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Public low-carbon related characteristics and their (dis) approval of nuclear energy in China against the backdrop of climate change: an analysis of influence mechanism

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Developing nuclear energy is a controversial issue despite its inherently low-carbon emissions life cycle. Considering low-carbon awareness, perception of barriers and low-carbon behaviors as important personal characteristics in the context of climate change, then how these characteristics will affect people's acceptance of nuclear energy? In this study, we explore the public low-carbon characteristics in China based on the latest representative national survey. The influence mechanism of individuals' low-carbon behaviors is analyzed by structural equation model (SEM). Then, we explore how the individuals' low-carbon characteristics relate to their attitudes toward nuclear energy. The results suggest that Chinese public has high low-carbon attitudes and values. However, lack of low-carbon knowledge, more perception of barriers and accordingly fewer low-carbon behaviors are still serious issues among the general public in China. Special attention should be given to the awareness–behavior gap, which can be mainly attributed to the existence of some barriers to performing low-carbon actions. Our survey suggests a higher proportion of people (approximately 88%) accepts nuclear energy development given some compensation. Perception of barriers and low-carbon habits are identified as important personal characteristics that can affect people's attitudes toward nuclear energy. To smooth the development of nuclear power, the government should help the general public to possess more knowledge on nuclear energy and climate change.

KEYWORDS

low-carbon awareness, perception of barriers, low-carbon behaviors, acceptance of nuclear energy, climate change

1 Introduction

China, where coal is the dominant energy source, has been the country with the highest greenhouse gas emissions since 2006 (Sun and Zhu, 2014; Wang J. et al., 2020). Amid great pressures from global climate change, the government has made great efforts to reduce greenhouse gas emissions in China (Dai, 2017; Zhong et al., 2024). Considering the characteristics of stable supply and low carbon emissions throughout its lifecycle, nuclear energy has become an important priority for the central government to reduce fossil fuels consumption in China. The State Council's 2030 Carbon Peak Action Plan proposes nuclear energy development as essential way to achieve green and low-carbon transition (Wang et al., 2024). By the end of 2023, 55 commercial nuclear power reactors were in operating in China with a total installed capacity of approximately 57.03 million kilowatts, second only to America and France worldwide. Nuclear power generation has been increasing over the past decade in China, reaching 433.4 billion kilowatts in 2023, or 4.86% of the nation's total power generation (China Nuclear Energy Association, 2024). Nuclear power eliminates the need for 123 million tons of standard coal in 2023 and thereby reduces emissions by 323 million tons of CO_2, 1.05 million tons of SO_2 and 0.91 million tons of NO_X. However, it should be noted that the proportion of nuclear power in the total power generation in China is still significantly lower than that in France (62.5%), South Korea (30.4%), United States (18.2%), Canada (12.9%) and even the global average (9.8%) (China Nuclear Energy Association, 2024).

The central government in China has promised to reduce carbon emissions through more effective strategies to reach a "carbon peak" before 2030 and achieve a "carbon neutrality" goal before 2060, its so-called "double-carbon" targets. Considering the urgency of reducing carbon emissions and the low carbon attributes of nuclear energy, promoting nuclear development has strategic value for China; thus, it has been taken seriously in almost all energy-related regulations, plans and policies. However, developing nuclear energy is still a controversial issue worldwide (Ho and Kristiansen, 2019; Sonnberger et al., 2021; Hassan et al., 2023). Among environmentalists, some consider nuclear energy as a "necessary evil" in the fight against climate change, while others strictly rule it out because of the potential environmental and human health risks. Residents may particularly worry about radiation risks and object to the construction of nuclear power stations in their neighborhood—the so-called not-in-my-backyard view (Hubbard, 2009; Ho and Kristiansen, 2019; Sonnberger et al., 2021). More specifically, public acceptance has fallen to very low levels following several serious nuclear accidents, e.g., the 1986 Chernobyl nuclear catastrophe and the 2011 Fukushima nuclear accident. Antinuclear movement outbreaks have thus occurred in many countries, including China, e.g., the antinuclear action in Jiangmen city, Guangdong Province, in 2013 (Kim et al., 2014).

It is also suggested that attitudes toward nuclear energy are constructed in specific social context, and the argument that nuclear energy can contribute to energy security originated during the OPEC oil crisis in the 1970s (Freudenburg and Rosa, 1984). As the risk of globle warming deepening, more and more countries worldwide promote low-carbon economy and society, implying the start of the new climate regime (Chung and Kim, 2018). Many politicians and researchers have begun to view nuclear energy development as an effective measure for mitigating global warming (Verbruggen and Laes, 2015; Arlt and Wolling, 2016; World Nuclear Association, 2025). In China, transitioning to a low-carbon economy and society is strongly advocated by the government (Ministry of Foreign Affairs, 2025). And the citizens are guided to green, low-carbon lifestyle. While there is already a comprehensive body of studies on public perceptions and acceptance of nuclear energy, the relationship between public low-carbon related characteristics and views on nuclear energy is by no means obvious. The signs (i.e., positive or negative) of these relationships provide basic knowledge regarding effective public communication strategies for nuclear energy. It is considered people who have higher climate change concerns, specifically pay more attention to carbon emission reduction actions in daily life (reflected by low-carbon characteristics in our study), should evaluate the low-carbon attribute much higher than their counterparts, accordingly, have higher acceptance for climate friendly energy. Postulating that attitudes toward nuclear energy are socially constructed, and there are different social framings of nuclear energy, amongst which there is a framing as a climate friendly energy source, we derive the research question "how are the public low-carbon related characteristics related to their (dis)approval of nuclear energy" under the background of global warming. Specifically, the low-carbon related characteristics are measured by people's low-carbon awareness, perception of barriers and low-carbon behaviors in daily life. And the influence mechanism of individuals' low-carbon behaviors are also thoroughly explored for a better undetstanding of the relationship between low-carbon behaviors in daily life and the acceptance of nuclear energy.

Our study mainly contributes to previous research from the following points. First, as our analysis is based on a recent, representative face-to-face national survey in the context of pursuit of the "double-carbon" targets, with random sampling and covering 18 provinces in China, it constitutes an important complement to studies at individual province level. Second, low-carbon awareness, perception of barriers, and low-carbon behaviors are all clearly measured in our conceptual framework to capture people's low-carbon related characteristics. Third, to the best of our knowledge, this is one of the few studies where the relationship between public (dis) approval of nuclear energy and their differences in low-carbon related characteristics are exhaustively discussed. Furthermore, for people who accept nuclear energy, how these low-carbon characteristics affect their willingness-to-forgo-compensation (WTFC) for the low-carbon attributes of nuclear energy in the reframing context is also explored, which can provide more information for the large-scale development of nuclear power in China.

We arrange the remainder of this paper as follows. In Section 2, literature review on the public acceptance of nuclear energy in the reframing context of mitigating climate change is conducted. A conceptual framework of public low-carbon related characteristics described by low-carbon awareness, perception of barriers, and behaviors is constructed based on the literature review. Hypotheses concerning the influence mechanism of individuals' low-carbon behaviors and how the low-carbon related characteristics affect people's attitudes toward nuclear energy are developed. Our survey and methods are then introduced in Section 3. We present the results and discussion in Section 4. Finally, our conclusions and the relevant policy implications are offered in Section 5.

2 Literature review and hypotheses

2.1 Public climate change concerns and nuclear energy acceptance

In the context of transitioning to a low-carbon economy, nuclear energy has been recognized as a solution to human energy problems by some political actors due to the low carbon emissions in its lifecycle (Chung and Kim, 2018). However, this trend has also been criticized by some environmental activists who argue that fighting against climate change by the use of nuclear energy is a risk–risk tradeoff (Bickerstaff et al., 2008), replacing the climate change risks with the risks from nuclear stations.

Some studies have explored whether this reframing strategy has positive impacts on public acceptance of nuclear energy, and most of those conducted in European countries reveal a modest or even negative impact. According to a study in the United Kingdom, the British public sees both global warming and nuclear development as problematic considering the risks and shows only a "reluctant acceptance" of nuclear development to combat climate change (Pidgeon et al., 2008). In a study conducted by Visschers et al. (2011) in Switzerland, the authors conclude that public perception of the benefits for climate change mitigation positively affects the acceptance of nuclear power development, but these effects are smaller than that of securing the energy supply. Based on the empirical analysis of 14 Western European countries including United Kingdom, Switzerland, France, Germany, Norway, etc., Arndt (2023) finds negative associations between climate change worries and nuclear energy preference, and concludes that energy security concerns instead of climate change concerns significantly improve public preferences of nuclear energy. Similar negative associations are found by Sonnberger et al. (2021) with survey data from four European countries (France, Germany, Norway and the United Kingdom) and by Chung and Kim (2018) in Korea. It seems that findings are different in U.S. and China. A survey conducted in U.S. suggests concern about climate change is associated with greater odds of acceptance of nuclear energy, while concern about nuclear waste is associated with the opposite (Dehner et al., 2023). For studies that focus on China, researchers choose climate change mitigation, maintaining energy security and price stability to build the benefits index of developing nuclear energy, and a positive relationship is revealed between the perception of benefits and nuclear acceptance (Wang et al., 2019; Wang F. et al., 2020). However, few of these studies on China have isolated the impacts of climate change concern.

The Fukushima accident has significantly changed people's attitudes toward nuclear energy even in the new climate regime. In Japan, the general public has expressed more negative attitudes toward nuclear power since the Fukushima accident. A survey shows that just over 20% of Japanese public agree with the risk-risk tradeoff (Poortinga et al., 2013). In Australia, a majority of respondents are not willing to accept nuclear power as an option to help tackle climate change, which are significantly different from the results before the Fukushima accident (Bird et al., 2014).

In general, it seems the relationship between public climate change concern and acceptance of nuclear energy is various across countries or regions, i.e., modest impacts, negative impacts and positive impacts are all possible. And revealing the relationship has not been given enough attention in China though public climate change concerns are expected to change significantly in the regime of pursing "double-carbon" targets nationwide and the priority of developing nuclear energy in China. Furthermore, the climate change concern index in previous studies is usually measured by one or more items that focus mainly on people's attitudes toward climate change, multidimensional measures that can better capture public climate change concerns have been largely ignored. Specifically, few studies have paid attention to people's perception of barriers and low-carbon behaviors in daily life, which can better describe their low-carbon characteristics, then can be more correlated with their attitudes toward nuclear energy in the new climate regime.

2.2 Public low-carbon awareness, perception of barriers, and behaviors

For a better reflection of people's climate change concern from the perspectives of awareness and actions, we try to capture people's low-carbon awareness, perception of barriers and low-carbon behaviors in daily life, including both subjective and objective indexes. Although there is no a widely accepted definition, researchers generally consider low-carbon awareness as a multidimensional construct, i.e., including low-carbon values, attitudes and knowledge (Abdul-Wahab, 2010). Values relevant to environmentalism are classified into three types: egoistic (i.e., concerning about the wellbeing of oneself), altruistic (i.e., concerning about the wellbeing of others) and biospheric (i.e., accounting for the nature intrinsically) (Stern et al., 1993; De and Steg, 2008; Steg, 2005). The first two categories are also combined as anthropocentric values, i.e., protecting environment for human benefits (Gagnon Thompson and Barton, 1994). Values are primary determinants of people's attitudes and behaviors (Schwartz et al., 2001; Chen et al., 2014), but the change of behaviors is generally influenced by multidimensional factors (Dietz et al., 2005). Some studies also suggest that Chinese residents are relatively less influenced by environmental values (Hu et al., 2016). Low-carbon attitudes refer to attitudes toward low-carbon issues (Abdul Aziz et al., 2015). People with favorable attiudes toward low-carbon issues tend to conduct more low-carbon actions (Gadenne et al., 2011). Knowledge, another important dimension of awareness, can be understood from two aspects, i.e., factual knowledge and action-related knowledge. For low-carbon knowledge, the former denotes to knowledge of the definitions, causes or consequences of low-carbon issues, while the latter refers to knowledge of relevant skills and possible actions (Schahn and Holzer, 1990). It is generally considered improving individuals' knowledge of low-carbon lifestyle encourages more low-carbon practices or behavior intentions.

Low-carbon behavior, usually viewed as a subset of pro-environmental behavior, has also not been clearly defined in the literature (Chen and Li, 2019). The low-carbon behaviors considered in many recent studies focusing on reducing energy consumption and carbon emissions include energy conservation, green product purchase, travel mode choice, and recycling activity (Bai and Liu, 2013). The main factors influencing low-carbon behaviors include three types: demographic characteristics (e.g., income or education), internal factors and external factors. Internal factors represent personal characteristics, abilities, subjective willingness, and perceived behavioral control, while external factors include economic factors, regional culture, social norms, etc., (Wang et al., 2021).

Regarding the relationship between awareness and behaviors, the level of awareness is typically higher than that of behavior—the so-called awareness-behavior gap (Van Raaij and Verhallen, 1983; Zhou et al., 2020). The theory of planned behavior (TPB) suggests behavior is triggered by both behavior intention and perceived behavior control (Ajzen, 1991). The attitude-behavior-external conditions (ABC) model also clearly proposes that behavior is determined by the internal and external conditions (Cialdini et al., 1981). Some barriers may prevent the transformation of awareness into behaviors, such as economic factors (Ozaki and Sevastyanova, 2011), lack of skills (Stern, 2000), or inconvenience (Barr, 2007).

Although low-carbon awareness has attracted greater attention from researchers, few studies fully illustrate public low-carbon characteristics by low-carbon awareness, perception of barriers, and behaviors. The influence mechanism of people's low-carbon behaviors is still unclear. National-level research is particularly lacking, hampering a better understanding of the relationships between individuals' low-carbon characteristics and their acceptance of nuclear energy in China, which then hinders more efficient policy-making for nuclear energy development.

2.3 Hypotheses

Our research aims to explore the factors that affect individuals' low-carbon behaviors, the path and relationships among these factors. Then we will relate individual's low-carbon characteristics with their attitudes toward nuclear energy. Firstly, the research tested the interaction between the factors representing low-carbon awareness based on the literature review.

H1. Low-carbon knowledge has positive impacts on low-carbon attitudes.

H2. Low-carbon knowledge has positive impacts on low-carbon values.

H3. Low-carbon values have positive impacts on low-carbon attitudes.

Following, this study tested the hypotheses regarding to the influences of the low-carbon awareness on individuals' low-carbon behaviors.

H4. Low-carbon attitudes have positive impacts on low-carbon behaviors.

H5. Low-carbon values have positive impacts on low-carbon behaviors.

H6. Low-carbon knowledge has positive impacts on low-carbon behaviors.

Similarly, we tested the hypotheses regarding to the influences of the low-carbon awareness on individuals' perception of barriers of low-carbon behaviors.

H7. Low-carbon attitudes have negative impacts on the perception of barriers of behaviors.

H8. Low-carbon values have negative impacts on the perception of barriers of behaviors.

H9. Low-carbon knowledge has negative impacts on the perception of barriers of behaviors.

Furthermore, for the relationships between individuals' perception of barriers and low-carbon behaviors, we hypothesized,

H10. Perception of barriers have negative impacts on individuals' low-carbon behaviors.

Considering the potential radiation risks of nuclear energy, it is common for the government to promote the development of nuclear power by compensating the residents near nuclear stations with monetary or non-monetary incentives (Lesbirel, 2003). Public acceptance of nuclear energy and the WTFC for the low carbon attributes represent the behavioral intention to reduce carbon emissions via energy choice. Individuals with different perceptions of climate change risks should therefore have different preferences of the low-carbon attributes of nuclear energy. Then, who are more likely to accept nuclear energy and forgo the compensation considering the individuals' low-carbon characteristics?

H11. More perceptions of low-carbon barriers negatively affect public acceptance of nuclear energy.

H12. More low-carbon behaviors in daily life positively affect public acceptance of nuclear energy.

The hypothetical structural model in our study is presented as Figure 1.

3 Methodology

3.1 Questionnaire

The questionnaire mainly includes four sections: the section for the introduction of the survey's purpose; the socioeconomic and demographic information on the respondents and their households; the measurement items of low-carbon awareness, perception of barriers, and behaviors; the introduction of nuclear energy, learning about people's attitudes toward nuclear energy and the valuation scenario based on Contingent Valuation Method (CVM) with the aim to reveal people' WTFC for the low-carbon attributes of this type of energy in the context of global warming.

We generated the measurement items of low-carbon characteristics based on a review of related literature and China's national conditions. To measure individuals' low-carbon awareness, items are developed using the dimensions of low-carbon values, attitudes, and knowledge as discussed in Section 2.2. Low-carbon values consist of two items to identify whether individuals care about low-carbon issues mainly for the wellbeing of humans or for the intrinsic values of nature. Items measuring attitudes are mainly designed to reflect people's views on the impacts of greenhouse gas emissions as well as their perceived responsibilities for climate change mitigation. For our measure of low-carbon knowledge, a four-question battery covering several aspects of climate change, e.g., definition, causes and consequences, is carefully designed. Items

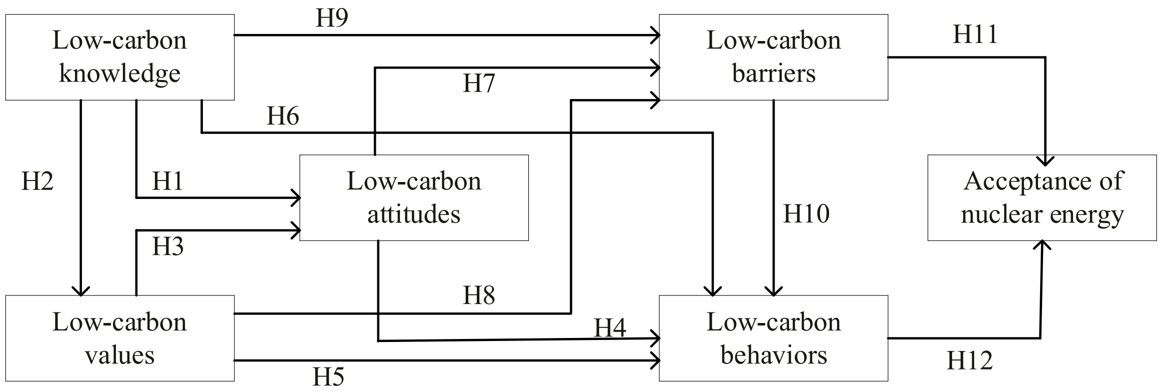


FIGURE 1
Hypothetical structural model of constructs.

adopted to describe low-carbon barriers include whether it is easier to participate in low-carbon activities and whether it is affordable to follow a low-carbon lifestyle, etc. For the low-carbon behaviors dimension, the most frequently mentioned low-carbon behaviors in recent studies (Abdul-Wahab, 2010), i.e., energy conservation, non-fossil fuel-based travel mode choice and preferences for green products, are queried. Response options for these items, excluding those for the knowledge construct, are measured by five-point Likert scale (Likert, 1932), with 1–5 representing "strongly disagree", "disagree", "general", "agree" and "strongly agree" respectively. Responses to the items for the knowledge construct can be "true" or "false".

Considering people may lack knowledge of nuclear energy in China (Su et al., 2024), the respondents are given a face-to-face introduction in a form of text with vivid pictures before we introduce the questions about peoples' attitudes toward nuclear energy and the valuation scenario. The specific information is related to a description of this type of energy, such as the essential attributes of nuclear power, the economic and environmental benefits (e.g., improving energy security, lower carbon emissions), the potential risks (e.g., radioactive threats, the waste disposal). Meanwhile, the nuclear power progress in China is highlighted with the vivid pictures, which contain the locations of nuclear power reactors, the nuclear policies, and the security management regulations.

In the valuation scenario based on the CVM, the respondents are first reminded that the government is considering development of nuclear energy to achieve its "double-carbon" targets. Following, a new nuclear energy development program mainly for energy structure improvement and reducing carbon emissions is presented. The respondents, as the representatives of their family, are told that they will receive a compensatory payment of 150 Yuan per month if the nuclear stations were built in their neighborhood. The bid is designed based on focus group discussions. Following the valuation scenario, respondents are asked whether they support developing nuclear energy. For those who answer "yes", we further ask for the maximum amount of compensation that the respondent would be willing to forgo per month for the low-carbon attributes of nuclear energy. Respondents are also told that the forgone compensation will be used for carbon emission mitigation programs. The payment card elicitation technique, which can improve the response rate than the open-ended technique and prevent the anchoring effect with the discrete choice format (Venkatachalam, 2004; Ryan et al., 2004), is adopted in our survey. Respondents are thus asked to choose their maximum WTFC amounts from a series of bids, i.e., 0, 5, 10, 20, 30, 50, 70, 100, 150 Yuan monthly. An open-ended question is also designed to elicit other WTFC amounts that are not on the payment card.

3.2 Sampling and data collection

The survey was launched by our research team and conducted by professional investigators through face-to-face interviews from December 2022 to January 2023. Compared to an online internet survey, a face-to-face survey increases the engagement and representativeness of samples, reduces misunderstandings and makes it more convenient for spontaneous questions. A total of 1,487 representative households, covering 32 prefectural-level or above cities[1] and 18 provinces in mainland China, were obtained. These provinces vary substantially in their geographical location, socioeconomic indicators, environmental conditions and energy consumption. The spatial distribution of the sampled households and nuclear power stations operating or under construction during the interviews is depicted in Figure 2.

The description of detailed socioeconomic and demographic characteristics of the sample are presented in Table 1. 33% of the respondents achieved bachelor's degree or above. 34% have a three-year-college experience and most of the rest just finished a high-school education. 63% of the respondents live in urban area, with a comparison of 37% in rural area. The sample covers various income groups, i.e., the average annually personal income for the low-income, lower-middle-income, middle-income and high-income groups (the 20% with lowest income, the second 20%, the third

1 In China, the cities with different administrative levels from upper to lower include municipalities, prefectural-level cities and county-level cities

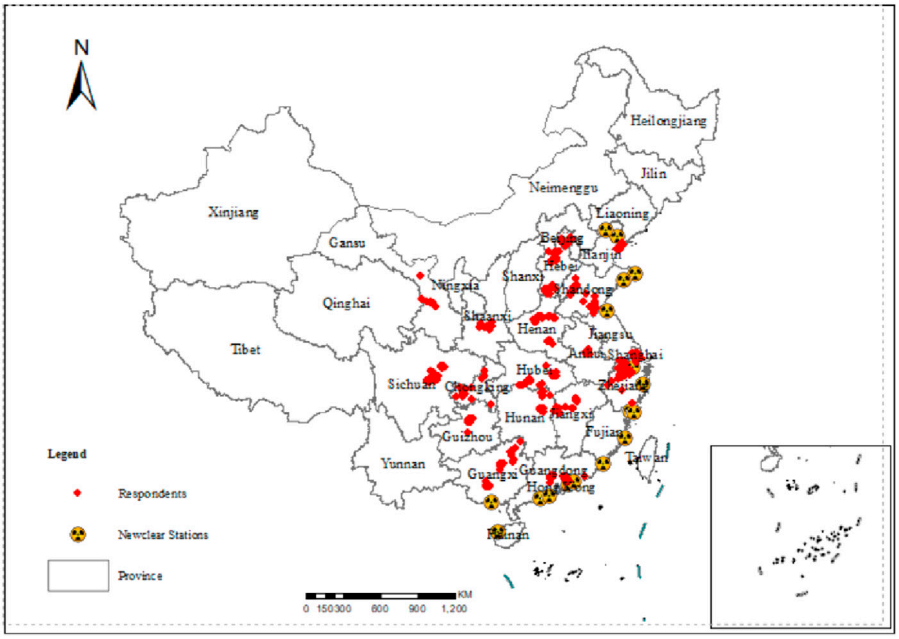


FIGURE 2
Distribution of samples and nuclear power stations.

20% and the rest) is 13.9, 32.5, 60 and 131.2 thousands Yuan respectively. 24% of the respondents come from cities or neighboring cities with nuclear stations and 76% live relatively far away from nuclear stations. So the sampling frame coverages groups with various socioeconomic and demographic characteristics and can be representative.

3.3 Analytic strategy and modeling

A structural equation model (SEM) approach was adopted to analyze the interactions between the different dimensions of low-carbon awareness, and how the individuals' low-carbon awareness and perceptions of barriers influence their low-carbon behaviors. The SEM method has been widely used to test and estimate causal relations (Byrne, 2001).

Researchers have developed alternative methods to analyze people's valuation (i.e., the WTFC values in this study) based on observations elicited by the payment card format, e.g., the ordered probit (logit) model (Hackl and Pruckner, 1999), the midpoint method (Cameron, 1987), and the interval regression technique (Cameron and Huppert, 1989). Interval censored regression is more efficient than the ordered probit (logit) model, as the former utilizes information on the scale of individual i's latent WTFC to produce an estimate of the standard variance, σ, of this latent variable (Yang et al., 2013). Interval regression is also more reliable than the midpoint method, as the latter assumes the center of the interval is the individual's true WTFC (Cameron and Huppert, 1989; Djemaci, 2015). Thus the interval analysis, which has been widely used in CVM studies such as Welsh and Poe (1998), Alberini et al. (2003), Yang et al. (2013) and Vossler and Holladay (2018), is performed in this study to analyze the impacts of individuals' low-carbon characterisitcs on their WTFC for the low-carbon attributes of nuclear energy.

Assume that individual i chooses bid j from the payment card, i.e., $p_{i,j}$, and $p_{i,j+1}$ is the next bid of j on the payment card. Thus, his or her true WTFC, the latent variable Y_i, is assumed to be located between the interval $[p_{i,j}, p_{i,j+1}]$ according to the interval censored regression. Accordingly, log (Y_i) is between log $(p_{i,j})$ and log $(p_{i,j+1})$. log (Y_i) can be expressed as a multiple linear function of low-carbon characteristics and other control variables to test our hypotheses H11 and H12, as shown in Equation 1:

$$\log (Y_i) = \beta_1 C_i + \boldsymbol{X}_i' \boldsymbol{\beta}_2 + \varepsilon_i, \tag{1}$$

where C represents individual's low-carbon characteristics, i.e., low-carbon awareness, the perception of barriers or low-carbon behaviors in daily life; X is a vector of control variables, and β_1, $\boldsymbol{\beta}_2$ are the parameters to be estimated. ε represents the error term.

3.4 Reliability and validity test

In Table 2, the items measuring low-carbon awareness, barriers, and behaviors indexes are presented together with their average scores and standard deviations. Reliability and validity are indispensable conditions for data measurement. Based on the 1,487 valid questionnaires, all 17 observed variables were tested for reliability and validity with SPSS 16.0. The total Cronbach α value of the data is 0.824, which meets the

TABLE 1 Description of sample characteristics.

Panel A: Categorial variables			
Variables	Definition	Frequency	Percentage (%)
Male	Male = 1	550	37
	Female = 0	937	63
University	Bachelor's degree or above = 1	487	33
	Otherwise = 0	1,000	67
Centralized heating	Adopt centralized heating system = 1	114	8
	Otherwise = 0	1,373	92
Individualized heating	Adopt individualized heating equipment = 1	293	20
	Otherwise = 0	1,194	80
Urban	Living in urban area = 1	940	63
	Living in rural area = 0	547	37
Nuclear_city	Coming from cities or neighboring cities with nuclear stations = 1	361	24
	Otherwise = 0	1,126	76

Panel B: Continuous variables				
Variables	Definition	Mean	Standard deviation	No. of obs.
Age	Years of age	26	7.94	1,487
Income	Annual personal income (ten thousand Chinese Yuan)	5.47	4.45	1,487
Electricity	Monthly average household electricity consumption (kWh)	288.78	165.01	1,468
Distance	Minimum distance from household to exiting nuclear power stations (kilometers)	494.54	354.13	1,297

Note: The minimum distance was calculated by the Nearest-Neighbor analysis with the ArcMap tool based on the longitude and latitude of the location of each household and nuclear power stations.

high confidence value standard (George and Mallery, 2003; Bai and Liu, 2013; Von Borgstede et al., 2013),[2] indicating that the reliability of the questionnaire is high. The Cronbach α values of the different factors are shown in Table 2. Factor analysis of each index yields a one-dimensional solution, indicating that the items regarding a certain index all measure the same latent dimension. The items for each index are also internally consistent according to the coefficients of Cronbach's α.

Kaiser Meyer Olkin (KMO) is an important validity indicator. The KMO values for the attitudes, knowledge, barriers, and behaviors indexes are all above 0.6, which demonstrates the validity of the measurement items; 0.5 for the low-carbon value index is obtained because we only have two items for this measure (Shrestha, 2021). The significant results of the Bartlett test of sphericity ($p < 0.001$) for all the indexes indicate the existence of correlations among measurement items for each index (Field, 2013). The factor loadings, indicating the strength of the correlation between observable variables and latent factors (Kline, 1994), range from 0.66 to 0.87 in our study, meeting the threshold of 0.60 (Bagozzi et al., 1991). Thus, the items are sound instruments for measuring the indexes of low-carbon values, attitudes, knowledge, barriers and behaviors.

2 Researchers have different opinions on the confidence value standard of α. George and Mallery (2003) suggested that the α should be closed to 0.6. However, according to Hatcher and Stepanski (1994), the internal consistency of the items is acceptable for the α value equal to or above 0.55 in social science with limited number of items in each index

4 Results and discussion

4.1 Descriptive statistics of individuals' low-carbon characteristics

Figures 3a,b depict respondents' low-carbon values, attitudes, knowledge, barriers, and behaviors. In general, individuals show higher self-assessed low-carbon values and attitudes, with average scores above 4 for each item in the two indexes, which can be mainly attributed to the urgency and importance of reducing carbon emissions widely advertised in various forms of mass media (Han and Sun, 2023; Tong et al., 2025). However, they may lack objective knowledge about climate change. As shown in Figure 3b, the percentage of respondents who provide correct answers to the

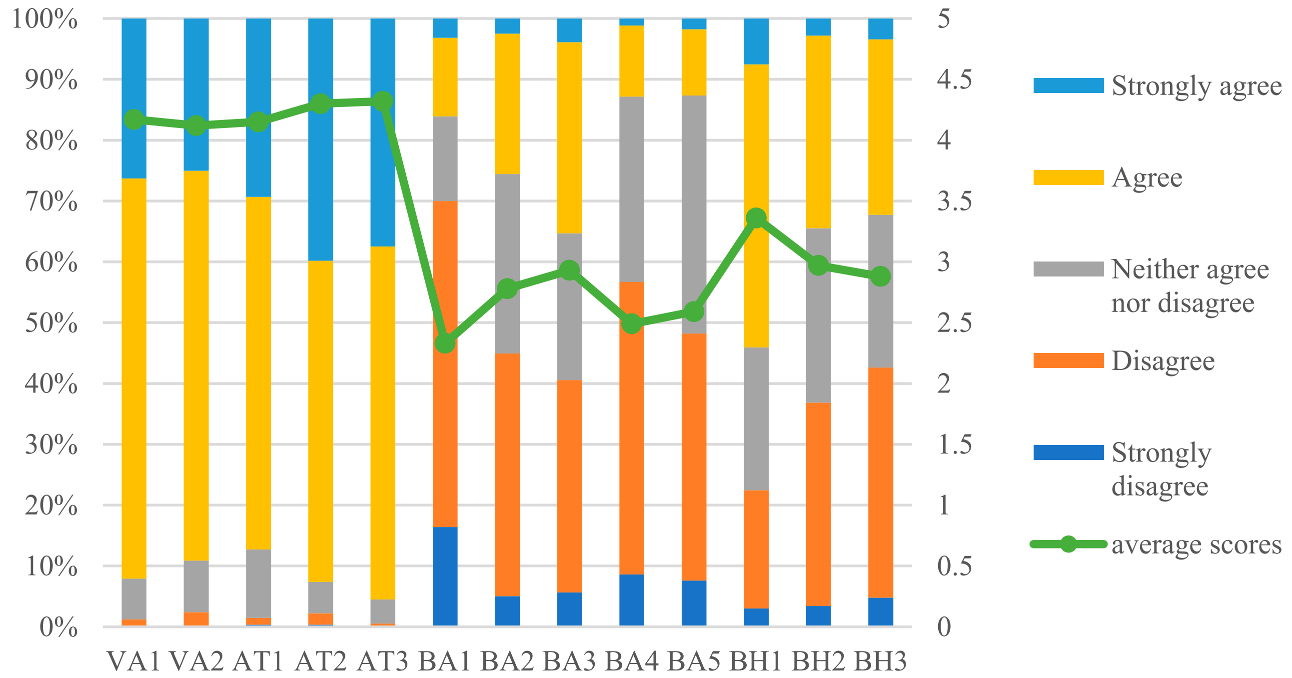
TABLE 2 Items per index of low-carbon characteristics: Mean values, standard deviations and factor loadings.

Measurement items for low-carbon indexes[a]	Mean (SD)	Factor loadings
Low-carbon values (Kaiser-Meyer Olkin = 0.50; Bartlett test of sphericity: $p < 0.001$; α = 0.66[b])		
1 (VA1)[c]. I am concerned about low-carbon issues, mainly for protecting natural environment and ecological system.	4.17 (0.60)	0.87
2 (VA2). I am concerned about low-carbon issues, mainly for human survival and development.	4.12 (0.65)	0.87
Low-carbon attitudes (Kaiser-Meyer Olkin = 0.66; Bartlett test of sphericity: $p < 0.001$; α = 0.67)		
3 (AT1). Enormous amounts of emissions of greenhouse gases from human activities will seriously threaten the natural environment and human society.	4.15 (0.68)	0.78
4 (AT2). Humans are responsible for climate change.	4.30 (0.68)	0.78
5 (AT3). Humans should make more efforts to reduce carbon emissions.	4.32 (0.58)	0.77
Low-carbon knowledge (Kaiser-Meyer Olkin = 0.73; Bartlett test of sphericity: $p < 0.001$; α = 0.70)		
6 (KN1). Climate change is only part of the natural cycle, which will naturally return to original level without any human intervention.	0.59 (0.49)	0.72
7 (KN2). Carbon dioxide accounts for a small portion of the atmosphere, which thus has little impact on climate change.	0.71 (0.45)	0.78
8 (KN3). Reducing carbon emissions specifically refers to reducing carbon dioxide, which does not include other greenhouse gases such as methane, hydrofluorocarbons and perfluorocarbons.	0.39 (0.49)	0.66
9 (KN4). The occurrence of extreme weather and cold waves is not linked to carbon dioxide emissions.	0.61 (0.49)	0.74
Low-carbon barriers (Kaiser-Meyer Olkin = 0.78; Bartlett test of sphericity: $p < 0.001$; α = 0.78)		
10 (BA1). I think a low-carbon lifestyle has little effect on climate change mitigation.	2.33 (1.00)	0.66
11 (BA2). I am not clear on the actions that are characterized by low-carbon emissions.	2.78 (0.94)	0.74
12 (BA3). It is difficult for me to find appropriate ways to participate in low-carbon activities.	2.93 (1.02)	0.75
13 (BA4). It is inconvenient for me to follow a low-carbon lifestyle.	2.49 (0.85)	0.75
14 (BA5). I cannot afford a low-carbon lifestyle.	2.59 (0.85)	0.78
Low-carbon behaviors (Kaiser-Meyer Olkin = 0.63; Bartlett test of sphericity: $p < 0.001$; α = 0.58)		
15 (BH1). I am adopting a low-carbon lifestyle, e.g., reducing the frequency of using air conditions, choosing non-fossil fuels.	3.36 (0.98)	0.71
16 (BH2). I do not consider the carbon emissions during its production process when I buy something[d]	2.97 (0.95)	0.77
17 (BH3). I do not care about whether it uses non-fossil fuels when I take a taxi[d]	2.88 (0.99)	0.73

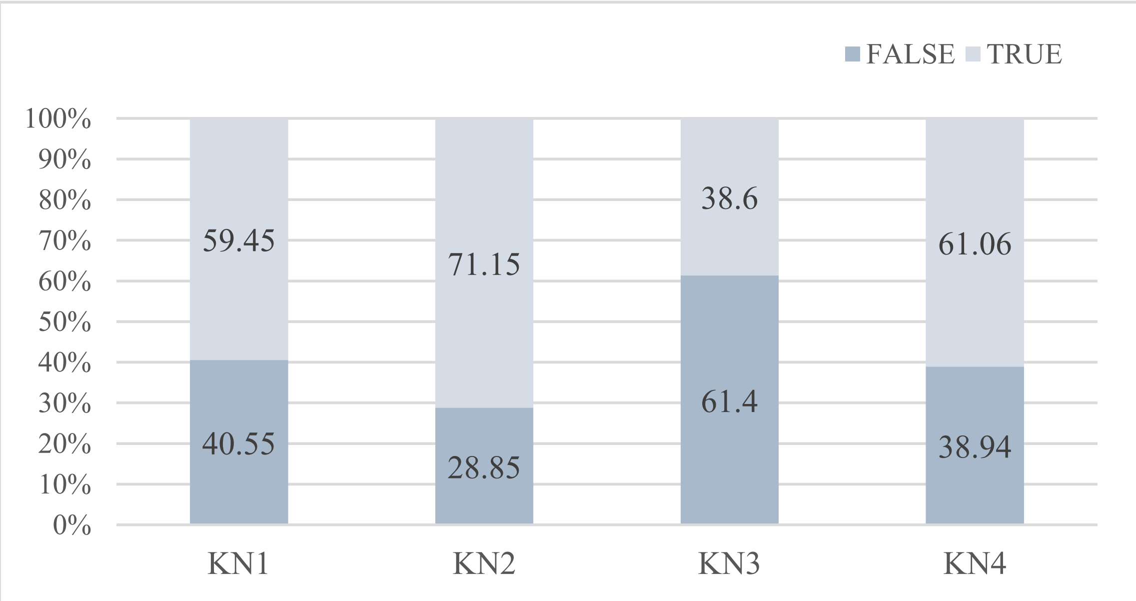
Note:
[a]All items are measured by 5-point Likert scales except items 6–9 (being binary, with 1 indicating right and 0 indicating wrong).
[b]α is the Cronbach's coefficient.
[c]The three characteristics after the sequence number, e.g., VA1, will be used to represent the specific measurement item in the rest of the paper. It is the same for the following measurement items.
[d]The negative statements are all recoded as positive when calculating the means of these items and the average scores of the low-carbon behaviors index. Thus, the higher the scores are, the more low-carbon behaviors there are.

four questions measuring knowledge levels remains at a relatively low level, ranging from approximately 40%–70%. The public also faces some barriers of low-carbon behaviors, e.g., inconvenience or unaffordability, as shown by the higher average scores on the items measuring barriers, which may prevent them from a low-carbon lifestyle. The relatively short period since the "double-carbon" targets were first clearly proposed and publicized, and the complexity of various factors influencing low-carbon behaviors (e.g., Chen and Li, 2019; Wang et al., 2021) may help to explain the lack of knowledge and the existence of barriers for general public. Accordingly, individuals generally do not pay enough attention to low-carbon actions in their daily life, such as shopping for green products or commuting by low-carbon transport. The significantly lower scores on items measuring low-carbon behaviors than those on values or attitudes indicate the potential awareness-behavior gap. It is suggested some barriers may prevent the smooth transition between awareness and low-carbon practices (Liu, 2012; Bai and Liu, 2013).

To better understand this low-carbon awareness–behavior gap caused by perception of barriers, we first classify the respondents into various groups according to whether they have scores above or below the sample's average on the low-carbon attitudes, values, knowledge, and behaviors indexes. Thus, the perception of barriers is compared between the group characterized by higher awareness–more behaviors and that with higher awareness–fewer behaviors. For this classification, we measure each of these indexes by averaging the scores of their corresponding items, as in previous studies (Von Borgstede et al., 2013; Sonnberger et al., 2021). That is, the low-carbon attitudes, values, barriers, and behaviors indexes all range from 1 (the lowest score) to 5 (the highest score), and the low-carbon knowledge index varies from 0 (the lowest level of knowledge) to 1 (the highest level of knowledge). As shown in Table 3, the proportions of individuals characterized by both a higher level of awareness and more behaviors, i.e., a higher consistency of values–behaviors, attitudes–behaviors, and knowledge–behaviors, are 17%, 26% and 28%, respectively; those



(a)



(b)

FIGURE 3
(a) Respondents' low-carbon values, attitudes, barriers, and behaviors [a] Note: [a] VA1–2: Two items measuring low-carbon values; AT1–3: Three items measuring low-carbon attitudes; BA1–5: Five items measuring low-carbon barriers; BH1–3: Three items measuring low-carbon behaviors. More information about each of these items please refer to Table 2. **(b)** Respondents' low-carbon knowledge [a] Note: [a] KN1-4: Four items measuring low-carbon knowledge. More information about each of these items please refer to Table 2.

TABLE 3 Distribution of respondents in various groups and their differences in perception of barriers.

Various groups	More low-carbon behaviors: average barriers scores (proportion of respondents)	Fewer low-carbon behaviors: average barriers scores (proportion of respondents)	Difference in average scores (t-test values)[a]
Low-carbon values: Higher level	2.11 (17%)	2.82 (15%)	0.71 (10.92)***
Low-carbon attitudes: Higher level	2.13 (26%)	2.75 (24%)	0.62 (13.16)***
Low-carbon knowledge: Higher level	2.15 (28%)	2.67 (24%)	0.52 (12.40)***

Note:
[a]The asterisks in this column indicate that the differences in perception of barriers between the group with more low-carbon behaviors and that with fewer low-carbon behaviors are statistically significant according to Student's t-test.
***p < 0.01.

TABLE 4 Indicators of goodness-of-fit of measurement models.

Standard values/Model values	RMESA	GFI	NFI	CFI	IFI	TLI	PNFI	PCFI
Standard	<0.08	>0.9	>0.9	>0.9	>0.9	>0.9	>0.5	>0.5
Model	0.054	0.955	0.908	0.923	0.924	0.905	0.728	0.740
Result	Ideal	Ideal	Ideal	Ideal	Ideal	Ideal	Ideal	Ideal

TABLE 5 Estimates of SEM.

Hypotheses	Relationships[a]	Estimate	S.E.[b]	C.R.[c]	P
H1	LCK→LCA	0.539	0.051	10.504	***
H2	LCK→LCV	0.167	0.057	2.942	**
H3	LCV→LCA	0.563	0.041	13.715	***
H4	LCA→LCBE	−0.027	0.109	−0.249	
H5	LCV→LCBE	0.070	0.082	0.845	
H6	LCK→LCBE	−0.024	0.096	−0.251	
H7	LCA→LCBA	−0.146	0.129	−1.135	
H8	LCV→LCBA	−0.287	0.096	−2.981	**
H9	LCK→LCBA	−0.897	0.111	−8.091	***
H10	LCBA→LCBE	−0.662	0.051	−13.067	***

Note:
[a]LCK: low-carbon knowledge; LCA: low-carbon attitudes; LCV: low-carbon values; LCBA: low-carbon barriers; LCBE: low-carbon behaviors.
[b]S.E. is the standardization error.
[c]C.R. is the critical ratio value.
**p < 0.01; ***p < 0.001.

with higher levels of values, attitudes or knowledge but lack actual actions are 15%, 24% and 24%, respectively. In the last column, we report the differences between the consistent group and inconsistent group in terms of their barriers to following a low-carbon lifestyle. Clearly, the barriers faced by the latter are significantly greater than those faced by the former, i.e., the awareness–behavior gap can be largely attributed to the existence of various barriers.

4.2 SEM analysis

In our study, the structural equation model was estimated by AMOS 26.0 software. The chi-square test of this model was significant ($\chi^2(109) = 582.672, p < 0.001$). Other statistical indicators as reported in Table 4, ie. RMSEA, GFI, NFI, CFI, IFI, TLI, PNFI, and PCFI, also confirm the goodness-of-fit of the model. Standardized coefficients of the SEM are reported in Table 5.

The three hypotheses regarding to the interaction between the indexes representing low-carbon awareness are all confirmed. Low-carbon knowledge has positive impacts on both low-carbon attitudes ($\beta = 0.539$, $p < 0.001$) (H1) and low-carbon values ($\beta = 0.167$, $p < 0.01$) (H2). The former is significantly larger than latter (0.539 > 0.167), which is different from Bai and Liu (2013) where the impacts of knowledge on attitudes are insignificant. Low-carbon values have a significantly positive impact on low-carbon attitudes ($\beta = 0.563$, $p < 0.001$) (H3), which confirms previous findings (Schwartz et al., 2001; Chen et al., 2014).

The hypotheses regarding to the direct impacts of different dimensions of low-carbon awareness on low-carbon behaviors are all rejected (H4, H5 and H6), which further reveal the value-action gap (Van Raaij and Verhallen, 1983; Flynn et al., 2009) or awareness-behavior gap (Bai and Liu, 2013). The results also fail to support the negative impacts of low-carbon attitudes on people's perception of barriers (H7). However, the path coefficients confirm higher scores on low-carbon values will help to reduce individuals' perception of barriers (H8, $\beta = -0.287$, $p < 0.01$). It also confirms the direct impacts of more low-carbon knowledge on reducing individuals' perception of barriers (H9, $\beta = -0.897$, $p < 0.001$). In addition, the significant path coefficients of H2 and H8 also suggest the indirect impacts of low-carbon knowledge on reducing individuals' perception of barriers via improving their low-carbon values.

Finally, consistent with our expectation, more perception of barriers will significantly reduce individuals' low-carbon behaviors in daily life (H10, $\beta = -0.662$, $p < 0.001$). As suggested by the theory of planned behavior, more perception of barriers means lower perceived behavior control, then an individual would have limited ability to overcome obstacles to follow a low-carbon lifestyle (Wang et al., 2021). And Knowledge is important personal resource that can affect an individual's perceived behavior control (Wang et al., 2021), which is consistent with our findings. In general, our research suggests that, higher low-carbon awareness (specifically higher low-carbon knowledge and values) will help to reduce the perception of barriers then indirectly encourage the residents to perform low-carbon actions, even though the limited direct effects of awareness on behaviors.

4.3 Public acceptance of nuclear energy and differences in low-carbon characteristics

For the 1,487 valid questionnaires, 88% of the respondents (1,302) show positive attitudes toward developing new nuclear power stations in their neighborhood, suggesting a high degree of public acceptance of this low-carbon energy in the reframing context in China. This acceptance degree is significantly higher than that revealed just after the Fukushima nuclear accident in 2013 of approximately 33% in China (Li et al., 2013). It is also higher than the acceptance level reported in other countries such as Germany (14%), Norway (18%), France (24%), the UK (45%) (Sonnberger et al., 2021), South Korea (52%), Morocco (13%) (Kovacs and Gordelier, 2009), Sweden (41%), and Austria (5%) (Liao et al., 2010).

This higher acceptance of nuclear energy in China can be mainly attributed to the great efforts made by Chinese government in advocating nuclear energy development in recent years (Wang J. et al., 2020). It can also be partially attributed to more nuclear knowledge provided in our survey. Here, we are interested in whether there are differences between the individuals who accept and object to nuclear development in terms of their low-carbon awareness, perception of barriers, and low-carbon behaviors. Thus, Student's t tests are performed to compare the low-carbon characteristics between these two groups. These results are shown in Table 6. The average scores on the three low-carbon awareness indexes are similar for the two groups, but the group that shows a positive attitude toward developing new nuclear power stations tends to perceive significantly fewer barriers of low-carbon actions and perform more low-carbon behaviors in their daily life. The similar scores between the two groups in low-carbon awareness confirm the findings of SEM, i.e., low-carbon awareness does not affect individuals' low-carbon behaviors directly. These results can help to explain H11 and H12. We will further test the two hypotheses in Section 4.4 based on the information of individuals' WTFC for low-carbon attributes of nuclear energy.

4.4 The impacts of low-carbon characteristics on the WTFC

In this part, we will test how individuals' low-carbon characteristics affect their WTFC for the low-carbon attributes of nuclear energy. Notably, we can observe WTFC responses only for the subsample who supports the new nuclear program. We also exclude the potential protesters which are identified from the zero WTFC observations by a follow-up question placed after the payment card valuation question.[3] Then we retain 1,202 observations for the following analysis. The distribution of individuals' responses to valuation questions is shown in Supplementary Appendix Table A1 in the Appendix. To test for potential sampling selection bias, we first estimate Heckman two-stage models (Heckman, 1979) for the whole sample. In the first stage, a probit selection model with the dummy representing support for the nuclear energy program or not as the dependent variable is estimated. The inverse of Mills' ratio derived from the first stage can then be included in the interval regression model at the second stage. Considering the highly asymmetrical distribution of the stated WTFC, we apply the logarithmic transformation to the WTFC data. Following previous studies (e.g., Liao et al., 2010; Huang et al., 2013; Sun and Zhu, 2014; Murakami et al., 2015; Cale and Kromer, 2015), we control for some individual characteristics, e.g., age and education, and household characteristics, e.g., urban or rural area, the

3 Responses of protesters are generally unable to reveal their true preferences (Meyerhoff and Liebe, 2006). We identify a person as protester instead of providing a real zero bid for the WTFC if he or she chooses one of the following two response options: "It is the government who should be responsible for the carbon emission reduction instead of the individuals" or "I do not believe the government would use the forgone compensation for carbon emission mitigation programs".

TABLE 6 Differences in low-carbon characteristics between individuals who accept and object to the new nuclear program.

Low-carbon characteristics	The group who accepts: Mean (SD)	The group who objects: Mean (SD)	Differences: Means (t values)[a]
Low-carbon values	4.1490 (0.5290)	4.1 (0.6164)	−0.0490 (−1.1536)
Low-carbon attitudes	4.2560 (0.4980)	4.2613 (0.5358)	0.0052 (0.1328)
Low-carbon knowledge	0.5793 (0.3446)	0.55 (0.3628)	−0.0293 (−1.0750)
Low-carbon barriers	2.6048 (0.6838)	2.7459 (0.6793)	0.1412*** (2.6298)
Low-carbon behaviors	3.0865 (0.7126)	2.9658 (0.7335)	−0.1208** (−2.1490)

Note:
[a]The asterisks in this column indicate that the differences in low-carbon characteristics between the group who accepts and objects to the new nuclear program are statistically significant.
**$p < 0.05$; ***$p < 0.01$.

TABLE 7 Interval regressions for the subsample with WTFC values.

Independent variables	Dependent variable: $[\ln(p_{i,j}), \ln(p_{i,j+1})]$				
	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
Low-carbon values	0.102*				
	(0.0542)				
Low-carbon attitudes		0.0332			
		(0.0596)			
Low-carbon knowledge			0.0608		
			(0.0856)		
Low-carbon barriers				−0.168***	
				(0.0424)	
Low-carbon behaviors					0.151***
					(0.0402)
Constant	1.757***	2.028***	2.130***	1.585***	1.702***
	(0.350)	(0.370)	(0.279)	(0.310)	(0.300)
Control variables[a]	Yes	Yes	Yes	Yes	Yes
City dummy	Yes	Yes	Yes	Yes	Yes
Ln (sigma)	−0.165***	−0.163***	−0.163***	−0.171***	−0.170***
	(0.0232)	(0.0232)	(0.0232)	(0.0232)	(0.0232)
Log likelihood	−1,936.75	−1,938.35	−1,938.26	−1,930.70	−1,931.48
N[b]	1,044	1,044	1,044	1,044	1,044

Note:
[a]The control variables include male, age, university, ln (income), electricity, centralized heating, individualized heating, urban, distance, distance*distance. More information about these variables is presented in Table 1.
[b]The subsample with WTFC values is used for the interval regression. The decrease in the number of observations is due to the missing values in the explanatory variables.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

minimum distance to the existing nuclear power stations, energy consumption status, in our models. We include the low-carbon awareness, perception of barriers and low-carbon behaviors indexes in Equation 1 separately and one by one to prevent any potential impacts on the precision of individual estimators caused by their correlations. Fixed effects at the city level are controlled for. The results of the first and second stages of the Heckman models are presented in Supplementary Appendix Tables A2, A3 in Appendix, respectively. In the second stage, the inverse Mills' ratios are only significant in the individual models (Model (1) and Model (2)) where our central variables, i.e., low-carbon values and attitudes, are insignificant. In contrast, the central variables, i.e., low-carbon barriers, and behaviors, are statistically significant in the models (Model (4) and Model (5)) without sampling selection bias revealed. Thus, the selection bias seems not to be a serious issue affecting the estimation of our central variables.

Then we only report the interval regression estimates based on the subsample that supports nuclear energy development in the main text, as shown in Table 7. To save space, only the coefficients of the central variables and constants are reported. The complete estimation results can be found in Supplementary Appendix Table A4 in Appendix. In general, both the Heckman two-stage estimation technique and the simple interval regression estimates reveal the significant, robust effects of perception of barriers and low-carbon behaviors on people's WTFC for the low-carbon attributes of nuclear energy. The fewer the perception of barriers to taking low-carbon actions, the more low-carbon habits stimulate the public to support this low-carbon energy development. Therefore, H11 and H12 are confirmed. Results also suggest the limited direct effects of low-carbon awareness on people's WTFC, which further confirms the awareness-behavior (behavior intention) gap. However, according to the results of SEM, more low-carbon knowledge and higher low-carbon values may indirectly stimulate the public to forgo more compensation via reducing their perception of low-carbon barriers.

5 Conclusion and policy implications

Public low-carbon awareness, specifically low-carbon attitudes and values, have significantly increased over the past decade in China. For example, Bai and Liu (2013) suggest that the average scores on low-carbon attitudes and values, measured by similar items to those in the present study via the five-point scale, among residents in Tianjin,[4] China, were all approximately 3.3 in 2012, much lower than the findings in our research. The significant increase in public awareness can be mainly attributed to the widespread broadcast of the potential risks of global warming and the urgency of carbon emission reduction. However, lack of low-carbon knowledge, more perception of barriers to perform low-carbon actions and accordingly fewer low-carbon behaviors in daily life are still serious issues among the general public nowadays in China. Special attention should be given to the awareness–behavior gap, which captures the contextual meanings associated with individuals' perception of barriers to reduce carbon emissions, and poses a great challenge to the formation of low-carbon lifestyles. According to the results of structural equation models, more low-carbon knowledge plays specifically important role in reducing individuals' perception of barriers of conducting low-carbon actions. Knowledge can also help to reduce perception of barriers via improving people's low-carbon values. Then the first step for Chinese government to close the awareness-behavior gap should be to help the general public possess more factual knowledge and action-related knowledge related to climate change and carbon emission reductions (Schahn and Holzer, 1990). Other measures to reduce the cost of low-carbon actions and improve the convenience for the public to act in a more low-carbon way should also be taken.

Although developing nuclear energy worldwide is controversial, the present study shows a higher acceptance of this low-carbon energy among the Chinese public based on a representative national survey. And most respondents indicate a positive WTFC for the low-carbon attributes of nuclear energy in the context of global warming. These results are significantly different from findings in other countries, such as Germany (Sonnberger et al., 2021) and Australia (Bird et al., 2014), where a much lower acceptance of nuclear energy has been revealed. Such inconsistent results can be mainly attributed to the great discrepancies in national conditions. Amid great pressure of reducing carbon emissions, the Chinese government gives much priority to nuclear energy development to improve energy structure and achieve "double carbon" targets, while most other countries have much less ambitious plans. The higher acceptance of nuclear energy revealed in our study can also partially come from the objective nuclear knowledge provided to respondents.

Low-carbon awareness, perception of barriers and low-carbon behaviors in daily life can be considered as important personal characteristics in the context of climate change, which will then influence individuals' attitudes toward low-carbon energy. In this study, we find people with less perception of barriers and more low-carbon habits are more likely to accept nuclear energy, and willingness to forgo more compensation for the low-carbon attributes. However, consistent with the influence mechanism revealed by SEM, the low-carbon awareness has limited direct effects on people's attitudes toward nuclear energy. Further considering factors affecting low-carbon barriers and the relationship between perception of barriers and low-carbon behaviors based on the results of SEM, it suggests more knowledge on nuclear energy and climate change may help to smooth the development of nuclear power in China, which is consistent with the findings in previous research (Jun et al., 2010; Contu et al., 2016). The Chinese government can make full use of website to popularize scientific knowledge on nuclear energy (Wang et al., 2019), such as developing official websites for the routine publication of information regarding regulations and standards of developing nuclear energy, monitoring environmental quality near nuclear power plants and risk assessment at every stage of nuclear programs, and providing opportunities for the public to express their opinions online. The benefits of developing nuclear energy in terms of the environment, economy and society, specifically the strategic implications for carbon peak and carbon neutrality goals, should also be clearly stressed. Moreover, inviting the public to regularly visit nuclear power plants could also be an effective way to improve their level of knowledge.

Considering the awareness-behavior gap, we suggest the indexes of low-carbon related characteristics to be generalized to other studies on different countries or regions for the revealing of the associations between climate change concern and nuclear attitudes. It should be noted that the nuclear energy has been clearly and comprehensively introduced to all of the respondents in our sample before their attitudes toward nuclear energy are asked. The influences of public nuclear knowledge are not the core question

4 Tianjin is located in the northeast of China with much better socioeconomic situations than the national average

that we tend to explore in this study. In future studies to capture the impacts of nuclear knowledge, respondents can be divided into two groups. One group, with no specific information about nuclear energy, can be asked their attitudes toward nuclear energy directly, with a comparison to another group given specific information.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

HS: Writing – original draft, Formal Analysis, Data curation, Methodology, Conceptualization, Investigation. XG: Writing – review and editing, Conceptualization. JW: Conceptualization, Writing – review and editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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