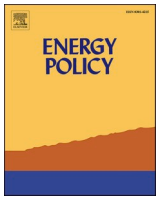
Energy Policy 198 (2025) 114478

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol



Carbon literacy, switching cost, and consumer choice: Evidence from the new energy vehicle purchase analysis

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ARTICLE INFO

Keywords:
Carbon literacy
Low-carbon consumption
Household decarbonization
Switching cost

ABSTRACT

Household carbon emissions account for a significant proportion of the national total emissions. Using a unique nation-wide survey data (CRECS) in 2022, this paper estimates the impact of carbon literacy on individual low-carbon consumption intentions and behavior by using the instrumental variable. Taking new Energy vehicle purchase as an example and we find that: first, carbon literacy only has a significant positive effect on purchase intentions, and does not have a significant effect on purchase behavior; and when the carbon literacy score increases by every 1 point, the individual purchase intentions will significantly increase by 0.224; second, the impact of carbon literacy on low-carbon consumption intentions is different cross education levels, regions and occupation types in China; finally, the difference between effect of carbon literacy on purchase intentions and behavior can be explained by the switching cost. The government ought to intensify efforts to enhance residents' carbon literacy and mitigate potential switching costs in order to foster low-carbon development.

1. Introduction

Since the Paris Agreement, participating countries have been obligated to promote a low-carbon transition to mitigate climate change and in a process to achieve carbon neutrality. Household carbon emissions account for approximately more than 60% of greenhouse gas emissions on a global scale and the proportion continues to increase (Ivanova et al., 2016; Xie et al., 2023). Hence, consumers are essential to be involved in carbon emission abatement. Many *soft* policy interventions have been implemented in recent years that try to promote the voluntary adoption of sustainable consumption practices, such as voluntary carbon offsetting, propaganda of low-carbon lifestyle, eco labeling, and subsidies for new energy vehicles (Soregaroli et al., 2021; Tao et al., 2021). However, some of these *soft* measures tend to be ineffective to include participation or carry forward slowly. Consequently, it is essential to explore the influence mechanism of the low-carbon willingness and choice of consumers.

Most of the research on the factors influencing low-carbon consumption behavior and mechanisms is based on classical behavior theory frameworks, such as Theory of Planned Behavior (Fishbein and Ajzen, 1977; Ajzen, 1991), Value-Belief-Norm Theory (Stern et al., 1999; Stern, 2000) and so on. And we can broadly categorize these factors into three groups. The first group encompasses sociodemographic factors, including gender, age, income, education level, rural/urban residence, marital status, family size, and family structure (Ding et al., 2018; Gambhir et al., 2015; Geng et al., 2017; Lin and Wang, 2021; Yi and Yan, 2020). The second group involves psychological factors such as attitudes, subjective norms, values, beliefs, norms, and perceived behavior (Ajzen, 1991; Cheng et al., 2020; Ding et al., 2017, 2018; Geng et al., 2017; Lin and Wang, 2021; Yang et al., 2016; Pothitou et al., 2016). The third group includes policy incentives like price incentives and informational guidance (Soregaroli et al., 2021). Some studies have attempted to use literacy to summarize individuals' knowledge, attitudes, and behavior in a certain field, such as environment literacy (Hungerford and Volk, 1990; Roth, 1992). However, there is a lack of a comprehensive indicator to measure literacy in low-carbon aspects, and its influence on residents' low-carbon consumption intentions and behaviors is still not enough discussed. Additionally, many studies are limited by data constraints, preventing from conducting robust causal identification and instead focusing on correlational relationships.

Furthermore, low-carbon consumption intentions and behavior are often not aligned and intentions frequently do not translate into actual behavior (Nguyen et al., 2019; Peattie, 2010). Fundamentally, one important reason for this gap can be understood as the existence of switching costs for consumers, but current literature does not focus on switching costs at the consumer level. The existing literature on

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https://doi.org/10.1016/j.enpol.2024.114478
Received 25 April 2024; Received in revised form 8 December 2024; Accepted 17 December 2024
Available online 27 December 2024

switching costs primarily examines firms' behavior when customers face switching costs (Klemperer, 1987, 1995; Jones et al., 2002). Various types of switching costs exist, including learning costs, transaction costs, sunk costs, search costs, and uncertainty costs (Nilssen, 1992; Jones et al., 2002). Existing research has explored switching costs across various fields, such as IT (Demirhan et al., 2007), airlines (Carlsson and Löfgren, 2006), agriculture (Mitchell, 2017), banking (Ho, 2015), among others. However, there is limited research on switching costs in the context of low-carbon consumption behavior.

Using the unique survey data of the Chinese Residential Energy Consumption Survey (CRECS), this paper constructs a carbon literacy indicator, and further examines the impact on the low carbon intentions and behavior of purchasing new energy vehicles. Moreover, considering the endogeneity issues such as omitted variables and reverse causality, we further use "Whether affected by climate change" as an instrumental variable to identify the causal effects of carbon sequestration on low-carbon consumption intentions and behavior. By employing the IV estimation method, we find that carbon literacy enhances the intentions to purchase new energy vehicles but does not influence actual purchasing behavior. Finally, the paper further discusses why the intentions are not aligned with the behavior from the perspective of switching costs.

Our paper contributes to the existing literature in the two folds. On the one hand, we use unique CRECS data, which possesses a certain degree of representativeness. The questionnaire covers the main aspects of green living for residents, providing a basis for measuring carbon literacy and the research topic of this article. And then we develop the framework of carbon literacy and use the data to measure this index. It provides a reference for research on carbon literacy theory. On the other hand, the paper finds that carbon literacy increases purchasing intentions but does not affect purchasing behavior, and further explores the role of switching costs in this gap, providing another explanation for the literature related to the intention-behavior gap.

The remainder of this paper is organized as follows: Section 2 presents the theoretical framework. Section 3 outlines the data utilized in this study and the construction of carbon literacy indicators. Section 4 presents the empirical methods employed and the selection of instrumental variables. Section 5 showcases the empirical results and Section 6 conducts a heterogeneity analysis. In Section 7, the discussion focuses on the role of switching costs in the relationship between carbon intentions and behavior. The concluding part includes the summary and policy implications.

2. Theoretical framework

The concept and measurement framework of carbon literacy can be traced back to the origins of environmental literacy. In the 1990s, numerous scholars conducted extensive research in the field of environmental education to develop a framework for defining the components of environmental literacy (Hungerford and Volk, 1990; Roth, 1992). Roth (1992) proposed a theoretical framework that defines environmental literacy from three dimensions: cognition, affection and behavior. This framework has since become the dominant approach in current research on environmental literacy (Roth, 1992). Environmental literacy encompasses a broad scope, and building on this foundation, scholars later proposed the concept of energy literacy, which is closely related to environmental literacy. Dewaters and Susan Powers (2013) developed a measurement standard for energy literacy based on environmental literacy, focusing on three dimensions: cognition (knowledge, cognitive skills), affection (attitudes, values, personal responsibility), and behavior. As attention gradually shifted to the low-carbon field, Liu and Cheng (2022) measured low-carbon literacy across three dimensions: low-carbon knowledge, attitudes, and behaviors. Furthermore, according to the Theory of Planned Behavior (TPB), which is an extension of the Theory of Reasoned Action (Fishbein and Ajzen, 1977; Ajzen, 1991), behavioral intention determines an individual's behavior and is influenced by three factors: behavioral attitudes, subjective norms, and perceived behavioral control.

Based on the existing literature, we put forward the concept of carbon literacy. Carbon literacy (also referred to as "low-carbon literacy") is the accumulation of knowledge, affection, and habitual behaviors regarding carbon reduction and energy conservation that individuals acquire and develop through learning. And this paper posits that carbon literacy can be divided into three components: carbon knowledge, carbon affection, and carbon habits.

Carbon knowledge refers to an individual's awareness and understanding of objective knowledge and developmental principles related to carbon. It comprises three main elements: basic knowledge, consequence awareness and practical skills. Basic knowledge represents an individual's understanding of scientific knowledge and policies related to carbon; consequence awareness mainly involves awareness of the impacts of climate change and energy-saving and emission-reducing activities; and practical skills indicate the degree to which individuals recognize whether certain behaviors in daily life leads to carbon emissions or affect climate change. Carbon affection encompasses values, attitudes, and self-efficacy concerning low-carbon issues. Values reflect an individual's understanding and judgment regarding low-carbon activities or behaviors; low-carbon attitude refers to an individual's behavioral inclination toward low-carbon activities; and low-carbon self-efficacy denotes an individual's subjective judgment about their ability to lead a low-carbon lifestyle or effectively engage in energy-saving and emission-reducing activities. Carbon habit refers to the behavioral tendencies that individuals have developed over time, which are relatively stable and resistant to change. Carbon habits can be divided into self-type and social-type. Self-type low-carbon habits are those formed independently or because the habits provide personal utility. Social-type habits are those developed within social groups (e.g., "peer effects") or because these habits contribute to society, thereby incentivizing individuals to maintain them.

The framework of carbon literacy and its mechanisms of influence can be shown in Fig. 1. Within this system, the components are not mutually exclusive. Carbon cognition is the starting point of the entire system, where individuals begin to engage with and understand carbon knowledge from a young age, gradually forming their own carbon cognition. As this knowledge accumulates, it progressively influences individuals' carbon values, attitudes, and self-efficacy, eventually shaping their carbon habits. These components interact dynamically. Ultimately, carbon cognition, affect, and habit together form an individual's carbon literacy, which, in turn, influences their low-carbon behavior and behavioral intentions. Generally, higher carbon literacy leads to stronger intentions and a greater likelihood of engaging in low-carbon behaviors. Fig. 1 illustrates the components of carbon literacy and their mechanisms of influence.

3. Data and variables

3.1. Questionnaire design and survey implementation

The data utilized in this paper are drawn from the China Residential Energy Consumption Survey (CRECS), with the current round of data collected from December 2022 to February 2023, representing the latest survey round of the program. The survey was conducted by a professional research company in China through field questionnaires. Regarding the sampling methodology, this data is obtained through stratified random sampling, addressing the following considerations: firstly, provinces were randomly selected, encompassing 18 provinces in the East, Central, West, North, and South regions. The sample size selection within each region is primarily aligned with the proportion of the overall number of provinces in each region. Secondly, within each province, two prefecture-level cities are randomly chosen, with coverage extending to urban, county, and rural areas. The distribution of sampling numbers between provinces and among cities, counties, and

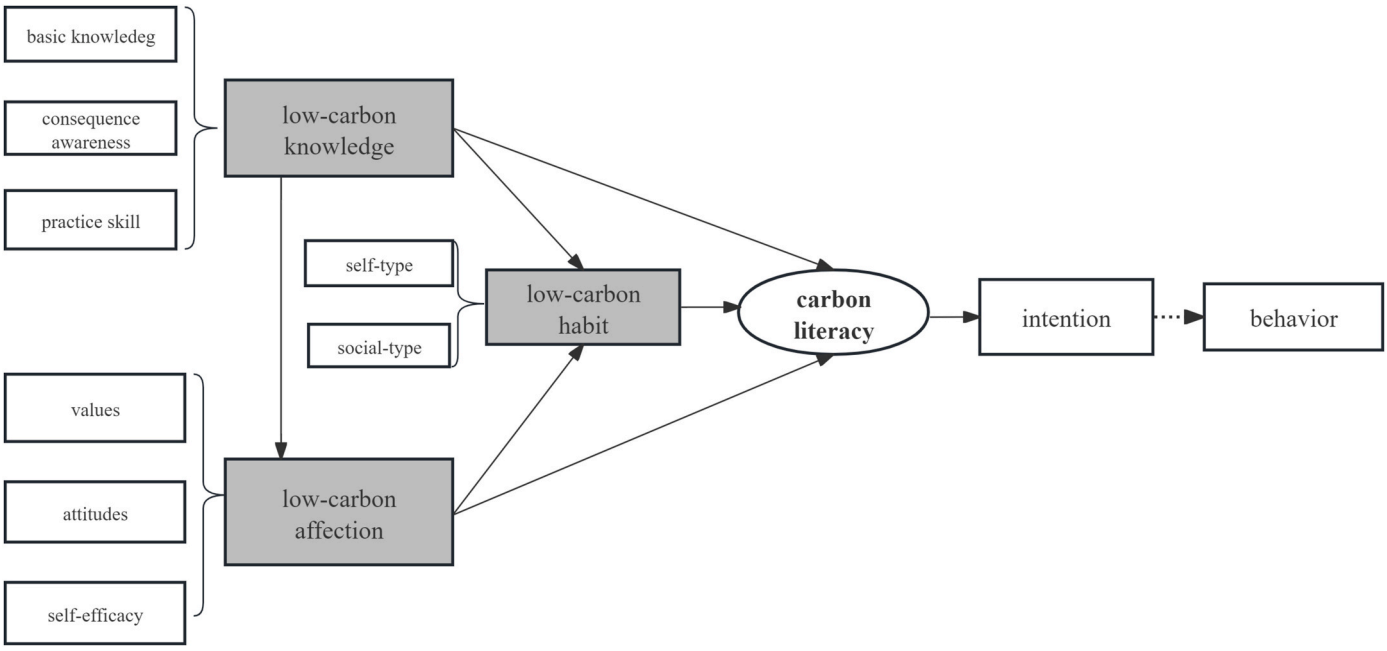

Fig. 1. Carbon literacy and its mechanisms of influence.

townships is in accordance with population proportions.

Regarding questionnaire design, the survey comprises various sections, encompassing basic individual information, carbon literacy, carbon footprint, and new energy vehicle purchase, among others. Simultaneously, the questionnaire includes several test questions to assure the validity of the final sample information. In terms of questionnaire implementation, an electronic format was utilized to mitigate issues such as respondent skipping or omitting answers. The survey was conducted through online recruitment and offline interception. A total of 1850 responses were collected from the recruitment fill-ins. Subsequently, to ensure the validity of the final sample information, the project team evaluated the questionnaire filling-in time. Responses with a questionnaire completion time of less than half an hour were deemed invalid and excluded from this section of the sample. The final total samples are 1850.

Furthermore, we provide a detailed visualization of the geographic distribution of our final sample in Fig A.1, showing representation across all regions. Given that the eastern region has the largest population, our sample selection reflects this demographic characteristic with a larger number of respondents from that area. Additionally, we compared our sample with data from the Seventh National Population Census. As shown in Table A.2, we find that, across most dimensions, our sample aligns with the principles of random sampling. However, since our sample was collected through a questionnaire survey, certain criteria had to be met—for instance, respondents needed to be capable of independently completing the questionnaire, which excluded children. Besides, to ensure the validity of the questionnaire, we excluded responses that were completed too quickly or had incorrect answers to control questions. As a result, there are slight deviations from the census data. Nonetheless, overall, our sample still maintains a reasonable degree of representativeness.

3.2. Construction of carbon literacy indicators

The overall framework for building carbon literacy scores is primarily based on existing literature, only with specific question items differing to some extent. As shown in Table 1, carbon literacy (also known as “low-carbon literacy”, LCL) mainly consists of three major categories: carbon knowledge (LCK), carbon affection (LCA) and carbon habit (LCH), and each major category contains 2–3 subcategories. Among them, the low-carbon knowledge section features correct answer, with the questionnaire offering three options: correct, incorrect and uncertain. A correct answer is scored as 1 point, and incorrect and uncertain answers are recorded as 0 points. In the low-carbon affection and low-carbon habit sections, the questions are graded subjectively on a scale of 1–5, with higher numbers indicating a stronger low-carbon orientation. To maintain weighting consistency during later carbon literacy calculation, we divided low-carbon affections and low-carbon habits by 5 on the basic of the original scores, resulting in each question item’s final score ranging from 0 to 1. The overall carbon literacy score is determined by summing the processed scores of each question item.

Upon calculation, the final scores for the carbon literacy questions are presented in Table A.3. The average scores for the three low-carbon awareness categories are 2.62, 3.57, and 3.014, respectively. This suggests that the general public possesses a relatively limited understanding of basic carbon-related knowledge but has clearer insights into the consequences of current global climate change and behaviors in daily life that contribute to carbon emission reduction. Except for questions 4 and 5, the scores for other questions were relatively typical, indicating respondents’ limited clarity on the definition of carbon neutrality and the attributes of nuclear power. In the low-carbon affections section, the average scores for the three categories are 4.02, 3.64, and 4.17, respectively. This implies that the majority of residents express support for emission reduction in terms of values, demonstrate willingness to take actions for carbon emission reduction in terms of attitudes, and exhibit self-efficacy in the process of reducing carbon emissions. Regarding low-carbon habits, the mean score for self-type low-carbon habits is 3.55, while the mean score for social-type low-carbon habits is 3.78. This indicates that the low-carbon habits of most residents can to some extent align with their self- or social-type values.

Additionally, there may be concerns regarding whether the absence of key indicators would affect the measurement of carbon literacy levels. To address this, we have attempted to demonstrate that our carbon literacy is relatively stable and consistent, effectively reflecting respondents’ literacy regarding low-carbon practices. We used Cronbach’s Alpha index to calculate the internal consistency reliability of our scale. Furthermore, we systematically removed 29 indicators to observe

Table 1
Carbon literacy scale components.

Component	Subcategories	Items
Carbon Knowledge (LCK)	Basics Knowledge (BSK)	The main cause of climate change is the massive use of fossil fuels (e.g., oil, coal) by humans, which produces large amounts of greenhouse gases such as carbon dioxide. Carbon emissions from the transportation sector are greater than those from the construction sector. * Industry is the main area of energy consumption and CO2 emissions in the country. Carbon neutrality means zero greenhouse gas emissions in China. * Nuclear power is a type of green power. *
	Consequence Awareness (CSA)	Carbon dioxide makes up only a small part of the atmosphere and has little impact on climate change. * Large quantities of greenhouse gas emissions will have a serious impact on the natural environment as well as on human society. Climate change has been an important cause of the high incidence of infectious diseases in recent years. The occurrence of extremely cold weather and cold snaps has nothing to do with CO2 emissions. * Climate change will elevate the incidence of flooding.
	Practical skills (PTS)	Consumption of meat foods causes more carbon emissions than a vegetarian diet. Short-haul airplanes are the most carbon-intensive (carbon emissions produced by traveling the same kilometers) mode of travel. Proper waste separation helps to save energy and reduce emissions. The production, processing and transportation of clothing generates carbon emissions. Use of computers, washing machines and refrigerators does not produce carbon emissions. *
Carbon Affection (LCA)	Values (VAL)	Humans should be working harder than they are now to reduce carbon emissions. Humanity is responsible for climate change. We don't have to worry about emissions reductions now because new technologies will be developed to solve the emissions problem for future generations. *
	Attitude (ATT)	I am willing to cut down on unnecessary shopping and usage in order to reduce emissions. I don't think low carbon living will do much to mitigate climate change. * I am not willing to change my existing living habits (e.g., use less air-conditioning, elevator, buy fewer clothes) to adapt to a low-carbon lifestyle because it would lower my quality of life. *
	Self-efficacy (SEF)	I believe that by working with others, I can contribute to the realization of the dual-carbon goal. I am willing to contribute to the realization of the dual-carbon goal by taking appropriate actions related to emission reduction.
Carbon Habits (LCH)	Self-type (SLH)	I would prefer to buy home appliances with energy efficiency labels, even if they would be more expensive. I am willing to take on additional financial expenditure (e.g. replacement of energy-saving light bulbs) for energy saving and emission reduction. I sometimes forget to turn off lights as I go, turn off electronic devices, unplug chargers, turn off faucets, use both sides of paper, and other energy-saving behaviors. *
	Social Type (SCH)	I would like to encourage my family to turn down the heat at night in the winter or turn up the air conditioning temperature at night in the summer to reduce emissions. My family, relatives, and friends and I often bring up topics related to carbon emissions in our conversations. I see people around me who will share low carbon life styles and feelings on social media and therefore change their behavior.

Note: The label * indicates that the item is reverse engineered.

changes in the index. According to Table A.1, we find that the changes are minimal, with the majority remaining around 0.75. This indicates that our indicators meet the consistency requirements (Nunnally and Bernstein, 1994), ensuring that the reliability of the scale is not compromised by individual questions. Thus, we can infer that even if we indeed lack some crucial indicators, this would not have a significant impact on the overall index's stability and consistency.

3.3. Description statistics

Table 2 illustrates the descriptive statistics of all variables employed in this paper. Simultaneously, we depict carbon literacy between intentions and behavior in Fig. 2. It is noteworthy that carbon literacy demonstrates a more substantial gap in different intentions compared to different behaviors, indicating that carbon literacy exerts a more pronounced influence on intention than behavior.

4. Empirical strategies

4.1. Benchmark models

Our objective is to investigate the influence of carbon literacy on residents' low-carbon consumption intentions and behaviors, with a specific focus on the purchase of new energy vehicles. Therefore, our primary emphasis is on understanding how carbon literacy impacts the intention and behavior of purchasing new energy vehicles. Regarding the regression strategy, we predominantly employ the logit model.

Given that the dependent variables in this study are either binary or ordered variables, the utilization of the binary logit model and ordered logit model offers distinct advantages for addressing this research problem, respectively. The binary logit model as a binary choice model is a generalized linear regression model that is often used to analyze the influences on behavioral choices. The biggest advantage of the logit model is the flexibility of the variables, the dependent variables can be continuous or discrete. The ordered logit model is a generalized linear regression model for situations when the dependent variable is ordered with multiple classes, and is often used to analyze the factors influencing behavioral choices. Our regression model is as follows:

$$y_i = \beta_0 + \beta_1 lcl_i + X\delta + \lambda_p + \varepsilon_i \quad (1)$$

The dependent variables y_i are new energy vehicle purchase intentions or behaviors. Specifically, the intention to buy is divided into five degrees from "very unwilling" to "very willing"; while the purchasing behavior is a dummy variable, "yes" or "no". The key independent variable is low carbon literacy (lcl_i). X is a series of control variables, and ε_i is the error term. Coefficient of interest in this study is β_1, which measures the impact of carbon literacy on willingness and behavior. At the same time, to control unobservable factors at the provincial level that may influence the results, we include provincial-level fixed effect λ_p in the model.

Selecting the intentions and behavior to purchase new energy vehicles (NEVs) as the dependent variables has significant policy and research implications and can also represent low-carbon behavior. First, China has introduced numerous incentive policies to increase the purchase rate of NEVs (Wang and Dong, 2016), but these policies have had very limited effects (He and He, 2015). Policymakers and the academic

Table 2
Descriptive statistics.

	Variable	Variable Definition	Obs	Mean	SD	Min	Max
independent variable	*lcl*	Carbon literacy scores	1850	19.83	3.184	8.80	27.80
dependent variable	*intention*	Willingness to buy, with 1–5 indicating very unwilling - very willing, respectively.	1850	3.601	0.999	1	5
	behavior	Purchase behavior, already purchased assigned a value of 1. Unpurchased assigned to 0	1850	0.114	0.317	0	1
control variables	*male*	Whether you are male	1850	0.371	0.483	0	1
	rural	Whether or not they are rural households	1850	0.365	0.482	0	1
	lnincome	Log of household income	1850	11.688	0.636	9.903	13.911
	age	Age	1850	34.78	10.37	17	74
	age2	Square of age	1850	1317	798.2	289	5476
	famnum	Number of persons in the household	1850	3.583	1.241	1	10
	oldrate	Elderly population (age $\geq$ 60) as a percentage of household size	1809	0.073	0.165	0	1
	childrate	Juvenile population (age $\leq$ 18) as a percentage of household size	1841	0.223	0.192	0	1
	party	Whether you are a party member	1850	0.082	0.275	0	1
	belief	Whether have religious affiliation	1850	0.006	0.080	0	1
	race	Whether you are Han Chinese	1850	0.947	0.224	0	1
	unmarried	Whether you are unmarried	1850	0.295	0.456	0	1
	eduy	Educational attainment	1849	13.94	2.573	6	22
IV	*influ*	Whether you affected by climate change	1850	0.381	0.486	0	1
new energy vehicle perceptual factors	*w1*	Familiarity with the performance of new energy vehicles	1850	3.221	0.960	1	5
	w2	New Energy Vehicles Pose a Risk of Identity	1850	2.959	0.868	1	5
	w3	Recognition of the high price of new energy vehicles	1850	3.282	0.958	1	5
	w4	Recognition of the high acquisition cost of new energy vehicles	1850	2.869	0.976	1	5

Notes: The new energy vehicles here do not consider hybrid vehicles, such as gas oil vehicles.

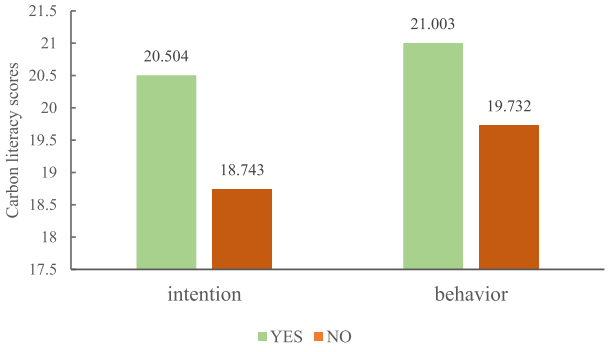

Fig. 2. Carbon literacy of different intentions and behaviors
Notes: For intention, "YES" is the respondents choosing "Very willing" or "More willing" to buy a new energy vehicle and "NO" is the respondent choosing "Not clear", "Relatively unwilling" or "Very unwilling"; for behavior, "YES" means the respondents have bought new energy vehicle and "NO" means not.

community are currently highly interested in the issue of NEV purchases (Wang et al., 2020). A substantial body of literature examines NEV purchasing behavior from the consumer perspective (Chen et al., 2019; Hardman et al., 2016; Wang and Dong, 2016; Newman et al., 2014), but most studies have not effectively identified the causal effects of literacy-related factors on this behavior. Additionally, research has shown that consumers may choose to purchase NEVs due to their environmental attributes (Axsen et al., 2013; Beck et al., 2017; Carley et al., 2013; Lai et al., 2015), suggesting that it can also be considered a form of pro-environmental behavior. Finally, to demonstrate that our conclusions are applicable to general low-carbon behaviors, we further examine the willingness and behavior to purchase low-carbon green clothing as dependent variables, thereby confirming the generalizability of our findings.

The choice of control variables is primarily based on related literature and practical reasoning. As mentioned above, the existing literature has extensively found that sociodemographic factors can influence environmental behavior (Ding et al., 2018; Gambhir et al., 2015; Geng et al., 2017; Lin and Wang, 2021; Yi and Yan, 2020), including gender, age, income, education level, rural/urban, marital status, family size, and family structure. So, we primarily select these sociodemographic factors as the control variables. Specifically, these include whether the respondent is male (*male*), age (*age*) and age squared (*age2*), the logarithm of income (*lnincome*), years of education (*eduy*), whether they live in a rural area (*rural*), whether they are unmarried (*unmarried*), the number of family members (*famnum*), the proportion of children (*childrate*), and the proportion of elderly individuals (*oldrate*), the respondent's political affiliation (*party*), religious belief (*belief*), and ethnicity (*race*) may also influence low-carbon behaviors to some extent; therefore, these three variables are also included as control variables. Furthermore, some literature suggests that certain low-carbon policies can affect low-carbon behaviors (Ding et al., 2018; Maki et al., 2016). The low-carbon policies of different provinces will also have an impact on the differences in low-carbon behavior, so we employ province fixed effects to account for these potential factors. And Table .2 present the more detailed information and descriptive statistics of the variables.

Specifically, in the regressions conducted in this paper, we choose "very unwilling" as the benchmark category for purchase intention and "did not purchase" as the benchmark category for purchase behavior. Since the dependent variable is categorical, using OLS regression may introduce bias. Therefore, this paper primarily uses the Logit model for regression.

4.2. Endogeneity and instrument variable

In identifying the impact of carbon literacy on low carbon consumption intentions or behaviors, it will inevitably be some potential endogenous problems as follows: firstly, there is omitted variables bias at the regional level. Individuals may generate overall carbon literacy differences due to factors such as the degree of regional economic development and culture, and these regional factors may in turn affect residents' low-carbon consumption intentions or behaviors, thus bringing bias to the regression results; Secondly, there is the issue of omitted variables at the individual level, such as family-related aspects or education, which may still introduce bias to the regression results. Thirdly, the challenge of causal effects identification arises. A simple Logit regression can only show a correlation between carbon literacy

and individuals' low-carbon consumption intention or behavior. However, it cannot identify whether carbon literacy has a causal effect on both.

In order to solve the endogeneity problems mentioned above, we select the variable "Whether or not you have been affected by climate change" (*influ*) as the instrumental variable of carbon literacy. In the questionnaire, we set the question "Has your life been affected by climate change?" and the responses can have five options: "Very much", "Partially", "Somewhat, but not much", "almost no effect" and "no effect at all", and we set the choices "Very much" and "Partially" to 1, otherwise to 0. A good instrumental variable should satisfy both the relevance constraint and the exclusion constraint. For relevance constraint, generally speaking, the more affected by climate change, the more individuals will pay more attention to climate change-related content, which will lead to a higher carbon literacy level of individuals. Furthermore, graphical and regression methods are used to verify this, respectively. As shown in Fig. 3, "whether or not you have been affected by climate change" has a significant positive correlation with carbon literacy; we can also use first-stage regression to test the constraint as shown in Table 4, and the result is that the instrument variable has a significant positive correlation with literacy. For the exclusion constraint, "whether or not affected by climate change" is a relatively exogenous variable, and the impact of climate variables is relatively random and almost uncontrolled by anyone, so it can be assumed that the variable fully satisfies the exclusion assumption. In summary, "Whether affected by climate change" is a good instrumental variable for carbon literacy.

Specifically, our IV estimation method is illustrated in equations (2) and (3). The control variables and fixed effects are consistent with those specified in the baseline model. In the first-stage regression, the dependent variable is carbon literacy (lcl_i), and the independent variable is the instrumental variable $influ_i$. In the second-stage regression, the independent variable is the fitted values of carbon literacy ($\widehat{lcl_i}$) and the dependent variable is low-carbon behavior/intention (y_i).

$$First-stage: lcl_i = \mu_0 + \mu_1 influ_i + X\varphi + \lambda_p + \xi_i \Longrightarrow \widehat{lcl_i} \tag{2}$$

$$Second-stage: y_i = \beta_0 + \beta_1 \widehat{lcl_i} + X\delta + \lambda_p + \varepsilon_i \tag{3}$$

5. Results

5.1. Benchmark regression results

The benchmark regression results are shown in Table 3. The results of the impact of carbon literacy on residents' low carbon consumption intentions and behaviors are reported in columns (1)–(2) and columns (3)–(4). As expected, the results reveal a significantly positive influence of carbon literacy on residents' willingness and behavior to purchase new energy vehicles, both at the 1% significance level. This finding is intuitively understandable. Specifically, holding other factors constant, higher levels of carbon literacy correspond to stronger intentions among residents to purchase new energy vehicles, consequently increasing the likelihood of actual purchase. Building on these findings, many policymakers assume that by enhancing residents' carbon literacy, they can subsequently boost the adoption rate of new energy vehicles. However, does this logic truly hold in China?

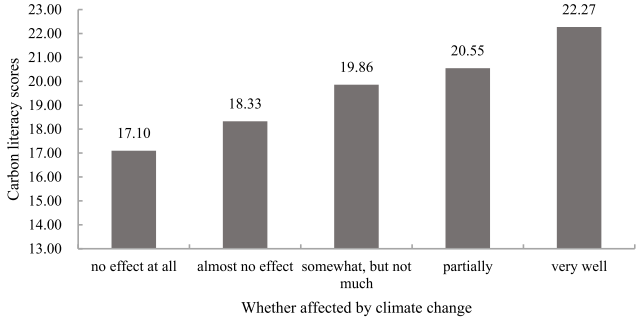

Fig. 3. Carbon literacy in different impacts of climate change.

Table 3
Benchmark regression results.

	intentions		behavior	
	(1)	(2)	(3)	(4)
lcl	0.179***	0.161***	0.132***	0.103***
	(11.41)	(9.46)	(3.53)	(2.72)
male		−0.487***		0.154
		(-4.05)		(0.78)
rural		−0.081		0.190
		(-0.82)		(0.84)
lnincome		0.243***		0.449**
		(2.58)		(2.40)
age		0.007		−0.012
		(0.21)		(-0.15)
age2		−0.000		0.000
		(-0.01)		(0.10)
famnum		0.078*		0.045
		(1.67)		(0.53)
oldrate		0.545**		−1.794**
		(2.02)		(-2.15)
childrate		0.113		0.256
		(0.37)		(0.46)
party		0.262*		0.233
		(1.70)		(0.62)
belief		1.059***		1.060
		(2.72)		(1.52)
race		−0.299		−0.228
		(-1.48)		(-0.42)
u nmarried		0.167		−0.367
		(0.99)		(-1.01)
eduy		0.008		0.032
		(0.37)		(0.67)
Constant			−4.705***	−9.900***
			(-5.77)	(-3.51)
Province FE	YES	YES	YES	YES
Observations	1850	1807	1850	1807
Pseudo R2	0.041	0.053	0.044	0.064

Notes: Ordered Logit produces multiple intercepts that are not shown in the benchmark regressions in this article due to space limitations. The regressions all use city-level clustering robust standard errors, with Z-statistics in parentheses below the regression coefficients in the tables, and *, **, and *** representing significance at the 10%, 5%, and 1% significance levels, respectively.

Table 4
Results of IV estimation.

	First stage regression		Second stage regression	
	lcl	*lcl*	intentions	behavior
	(1)	(2)	(3)	(4)
Influ (IV)	1.516***	1.207***		
	(7.21)	(7.16)		
lcl			0.224***	0.007
			(4.39)	(0.63)
Controls	No	YES	YES	YES
F value			74.484	74.484
Province FE	YES	YES	YES	YES
Observations	1850	1807	1807	1807
R-squared	0.054	0.214	−0.053	0.037

Notes: The regressions employ city-level clustering for robust standard errors, with t-statistics or Z-statistics presented in parentheses below the estimation coefficients in the tables. Significance levels are denoted by *, **, and ***, representing significance at the 10%, 5%, and 1% levels respectively.

5.2. IV estimation results

As previously mentioned, the benchmark regression may suffer from endogeneity issues and does not allow for causal identification. Therefore, in this section, we employ an instrumental variables (IV) strategy for re-estimation. Table 4 presents the IV estimation results, with columns (1)–(2) representing the first-stage regression outcomes and columns (3)–(4) indicating the second-stage estimation results. First-stage results indicates the instrument variable has a significant positive relationship with carbon literacy at the 1% significance level, which also provides empirical evidence regarding the suitability of our chosen instrumental variable, confirming its compliance with the relevance assumption.

The second-stage estimation results reveal that higher carbon literacy does still lead to higher intentions to purchase new energy vehicles for respondents, for every 1-point increase in the carbon literacy scores, the willingness to purchase will be increased by about 0.224, and it is significant at the 1% significance level. However, the effect on the actual purchase behaviors is not significant, which indicates that an enhancement in carbon literacy does not necessarily stimulate the purchase of new energy vehicles. In fact, existing literature also has already paid attention to intention-behavior gap (Carrington et al., 2014). Surprisingly, the IV estimation results are completely different from benchmark results. At the same time, we also use the IV-probit method in appendix Table A.5 and we find that carbon literacy increases purchasing intention but does not affect purchasing behavior. This shows that our estimation results are robust.

Clearly, in the process of carbon literacy influencing residents' low-carbon consumption, it can affect intentions but not necessarily behaviors, indicating a significant gap between intentions and behaviors. However, a potential question may arise regarding the externality of the conclusion and the representativeness of the specific issues studied. To address this concern, we conduct an extrapolation analysis focusing on the clothing sector, as presented in Table A.4, and arrive at the same conclusion. The estimation results also indicate that residents with higher levels of carbon literacy are more inclined to purchase environmentally friendly clothing. However, in practice, this does not translate into an actual increase in purchases.

5.3. Further analysis

In the previous analysis, it's found that carbon literacy only has an effect on low carbon consumption intentions and has no effect on low carbon consumption behaviors. Therefore, in the next analysis, we will focus on the effect on intentions and further analysis how the different components of carbon literacy affect residents' low-carbon consumption intentions. Among the three components of carbon literacy, carbon knowledge belongs to the more objective knowledge content, while carbon affection is a very subjective affectional attitude, and carbon habit is a habit accumulated over time.

The estimation results are shown in Table 5. It can be seen that the three components of carbon literacy all have a positive and significant impact on the purchase intentions of new energy vehicles; at the same time, through the comparison, it is found that among the three indicators, carbon habit has the greatest influence, followed by carbon affection, and finally low carbon awareness. The results indicate that, compared to a greater carbon knowledge, cultivating more frequent low-carbon habits tends to significantly enhance residents' willingness to purchase new energy vehicles. The results once again confirms the importance of habits in energy consumption in existing literature (Marechal and Lazaric, 2010).

5.4. Robustness test

In the next, we use the method to make robustness tests and the results are shown in Table 6. Meanwhile, considering that carbon literacy only has a causal effect on residents' behavioral intention, but not on actual behavior, the robustness test in this section focuses on residents' behavioral intention. The three methods all suggest that carbon literacy has a positive and significant effect on purchase intention, and the difference with the value of the benchmark regression is not too big, which indicates that the main conclusions of the benchmark regression have good robustness.

In the following section, we conduct robustness tests using three methods, and the results are presented in Table 6. Given that carbon literacy appears to exert a causal influence solely on residents' low carbon consumption intentions rather than their actual behaviors, the robustness tests in this segment concentrate on the effect on the residents' intentions. All three methods consistently demonstrate that carbon literacy exerts a positive and statistically significant impact on purchase intentions. Moreover, the estimated parameters from the robustness tests exhibit minimal deviation from the estimation results presented earlier, indicating the robustness of the estimations in this study.

Table 5
Regression results of the three components of carbon literacy on intentions.

	Logit		
	(1)	(2)	(3)
c_lck	0.131***		
	(6.73)		
c_lca		0.653***	
		(7.73)	
c_lch			1.125***
			(9.84)
Controls	YES	YES	YES
Province FE	YES	YES	YES
Observations	1807	1807	1807
Pseudo R2	0.040	0.050	0.065

Notes: *lck* stands for carbon knowledge, *lca* for carbon affection, and *lch* for carbon habit; The variable prefixed with " *c_*" indicates that the variable is decentralized.

5.5. Heterogeneity analysis

This section will analyze the heterogeneity in the impacts of carbon literacy on residents' low carbon consumption intentions from three aspects, including different education levels, different occupation types and different regions.

5.5.1. Education levels

The impact of carbon literacy on intentions towards low-carbon consumption may exhibit variation across different levels of education. Therefore, this subsection delves into the heterogeneity of education levels. Due to constraints in the size of the regression sample,[1] we segment the sample into three distinct categories: Junior school and below, senior high school, and University and above. The estimation results are presented in Table 7. Among respondents with educational backgrounds up to junior high school, the results indicate significance at the 10% level only, suggesting insufficient evidence to establish a significant effect of carbon literacy on consumption intentions within this group. Conversely, among those with senior high school and university education levels and above, carbon literacy demonstrates a notably positive and significant influence on the inclinations to purchase new energy vehicles. However, it's crucial to note the issue of weak instrumental variables within the sample of high school respondents, as

[1] There are only 21 samples that can be used at the primary education level and only 17 samples that can be used at the master's level.

Table 6
Robustness test results.

	Random sampling	Key variable Replacement	Supplementary variables
	(1)	(2)	(3)
lcl	0.171***	0.194***	0.106***
	(5.00)	(5.08)	(3.25)
w1			0.342***
			(12.48)
w2			−0.119***
			(-4.63)
w3			−0.092***
			(-4.23)
w4			−0.120***
			(-5.04)
Controls	YES	YES	YES
F − value	134.796	168.336	147.486
Province FE	YES	YES	YES
Observations	1459	1807	1807
R-squared	0.052	0.103	0.261

Notes: 1. Random sample method is randomly selecting 80% of the sample and the results of the regression are shown in column (1); 2. key variable replacement is re-fitting carbon literacy by changing the weights of each component of carbon literacy, and the three components of the new carbon literacy have the same weights; 3. Supplementary variables is adding explanatory variables that may be potential, important and significant; 4.The adding four explanatory variables: knowledge perception of new energy vehicles (w1), which indicates whether respondents are familiar with the performance (such as range, charging time, acceleration, driving comfort, etc.) and cost of new energy vehicles; new energy risk perception (w2), which indicates the degree to which respondents agree with the risks that new energy vehicles may bring; and new energy purchasing cost (w3), which indicates whether respondents agree with the risk of new energy vehicles; and whether respondents agree with the cost of purchasing new energy vehicles. The cost of purchasing a new energy vehicle (w3), indicates whether the respondent agrees that the purchase price of new energy vehicles is very high; the cost of using a new energy vehicle (w4), indicates whether the respondent agrees that the cost of using a new energy vehicle is very high; the above four variables are from "strongly agree" to "strongly disagree" in five degrees.

evidenced by the small F value. Consequently, the reliability of the regression results within this subset is questionable. Therefore, the conclusion can only be drawn that the impact of higher carbon literacy on intentions towards low carbon consumption is more pronounced within the "university and above" education group. This implies that enhancing people's educational attainment is vital for maximizing the efficacy of carbon literacy initiatives.

Education plays an important role in promoting residents' willingness to low-carbon behavior. Low carbon education should be incorporated into the education system to improve the public low-carbon literacy. At the same time, the promotion of low-carbon policies should focus on high school and above groups. For junior high school and below, we should focus on publicity and education, improve carbon literacy, and adopt some necessary economic subsidies.

5.5.2. Occupation types

The impact of carbon literacy on intentions toward the purchase of new energy vehicles may vary across individuals employed in different industries. The estimation results are shown in Table 8. For the residents worked in first industry sectors, there is no discernible evidence to support the notion that carbon literacy significantly influences purchase intentions. However, for individuals employed in the secondary and tertiary industry sectors, carbon literacy exerts a statistically significant positive effect on purchase intentions, at the 1% significance level. Moreover, it's notable that the magnitude of this effect is greater within the secondary industry compared to the tertiary industry. These findings suggest that the influence of carbon literacy on individual purchase intentions predominantly manifests within the secondary and tertiary industries. Consequently, policy initiatives aimed at enhancing residents' carbon literacy should primarily target individuals engaged in the secondary and tertiary industry sectors.

Table 7
Estimation results of education heterogeneity.

	Junior high school and below	senior high	University and above
	(1)	(2)	(3)
lcl	0.145*	0.310***	0.139***
	(1.73)	(4.43)	(3.92)
Controls	YES	YES	YES
Province FE	YES	YES	YES
F − value	20.658	18.046	124.313
Observations	226	374	1207
R-squared	0.028	−0.372	0.132

Notes: Senior high includes general high schools, vocational schools and technical schools (9 < education years ≤ 12); "University and above" includes university and college (education years > 12).

Table 8
Estimation results of occupation-type heterogeneity.

	First industry	Second industry	Tertiary industry
	(1)	(2)	(3)
lcl	0.698	0.179***	0.148***
	(1.48)	(3.96)	(3.95)
Controls	YES	YES	YES
Province FE	YES	YES	YES
F − value	1.167	49.400	115.874
Observations	139	310	1289
R-squared	−2.132	0.132	0.084

Therefore, when promoting demand-side emission reduction, priority should be given to residents engaged in the secondary and tertiary industries to reduce policy resistance. For residents engaged in the primary industry, it is necessary to first improve the carbon literacy level of this group through education and publicity, and actively take some economic support measures to promote their low-carbon behavior.

5.5.3. Regions

The impact of carbon literacy on intentions towards low-carbon consumption is likely to exhibit variability across different geographical regions. In this section, the sample is stratified into three distinct regions: East, Central, and West, for regression analysis, with the results presented in Table 9. Given the unique characteristics of Sichuan and Chongqing, the Western region is subject to a separate regression analysis after their exclusion (column (4)). The findings reveal a consistent positive effect of carbon literacy on the intentions to purchase new energy vehicles across all regions. However, it is noteworthy that there is insufficient evidence to support the impact of carbon literacy within the Western region, excluding Sichuan and Chongqing. This underscores the necessity for policy initiatives aimed at promoting residents' carbon literacy to be tailored according to specific regional considerations.

Consequently, considering regional heterogeneity is very necessary when promoting demand-side emission reduction policies and priority should be given to the implementation in the eastern and central regions. For the western region, the residents' willingness to low-carbon behavior should be improved through economic support, education and publicity activities.

6. Discussion the role of switching costs

In this section, we delve deeper into the reasons for the gap between the intention and behavior of NEVs purchase. When residents consider switching from traditional behaviors to low-carbon behaviors, the

Table 9
Estimation results of region heterogeneity.

	The East	The Center	The West	The West1
	(1)	(2)	(3)	(4)
lcl	0.150***	0.236***	0.114**	0.155
	(2.91)	(4.69)	(2.06)	(1.50)
Controls	YES	YES	YES	YES
Province FE	YES	YES	YES	YES
F − value	76.012	43.977	44.405	66.910
Observations	862	549	396	223
R-squared	0.074	−0.065	0.153	0.118

Notes: Although Sichuan province and Chongqing province belong to the West of China, they are more developed than other provinces in the West, most of provinces in the Center and some of provinces in the East. So, these two provinces' carbon literacy are higher as shown in Fig.A.2. The fourth column "the West1" indicates the removal of Sichuan and Chongqing regions.

primary switching costs including income constraints and sunk costs play a crucial role.

On one hand, income constraints refer to the higher costs typically associated with adopting low-carbon behaviors, which significantly hinder residents from switching from traditional to green, low-carbon behaviors (Bai and Liu, 2013; Wang et al., 2021). Taking NEV purchases as an example, compared to conventional vehicles, NEVs tend to exhibit higher purchase prices and maintenance costs, particularly in their early stages of development. Factors such as higher initial prices, limited range, and insufficient charging infrastructure all contribute to raising consumers' perceived costs. As a result, although consumers may have the intention to purchase NEVs, their actual purchasing behavior is often constrained by their financial capacity. On the other hand, sunk costs that consumers have already invested in traditional behaviors might prevent from low-carbon switching behaviors (Polites and Karahanna, 2012). These sunk costs make consumers less willing to switch to low-carbon behaviors. For instance, in the context of NEV purchases, if a consumer has already purchased a conventional vehicle, the long replacement cycle of vehicles often makes them less inclined to buy a new NEV.

Based on the above idea, we start to identify the two kinds of switching costs by adding the interaction term between carbon literacy and the logarithm of income (*lcl* × *lnincome*) and the interaction term between carbon literacy and "whether or not they own a conventional vehicle" (*lcl* × *traditioncar*), and using the IV to estimate. The results are shown in Table 10. We can find that, the interaction term (*lcl* × *lnincome*) has a positive effect on purchasing behavior and is significant at the 1% level of significance. It indicates that income plays an important role in the process of carbon literacy influencing purchasing behaviors. The interaction term (*lcl* × *traditioncar*) has a negative influence on purchasing behavior and is significant at 1% level of significance. This suggests that if residents have purchased a traditional car, it has a significantly negative effect on carbon literacy influencing new purchasing energy vehicles behaviors. At the same time, we also report the effect of these two interaction terms on residents' intentions in columns (1) and (2). We find that "whether or not one has purchased a traditional car" still can be switching costs in changing low carbon intention but the income will not affect. Indeed, it is intriguing that consumers only consider income constraints when they are actually making a purchase.

For income constraints, consider promoting a series of initiatives to reduce barriers in terms of income, such as promoting subsidies in the area of new energy vehicles and carbon inclusion at the level of other small daily behaviors to incentivize people to make a low-carbon transition at the consumption level. For the transition costs, it is important to make low carbon products more attractive and convenient for people.

Table 10
Estimation results of switching costs.

	intentions		behavior	
	(1)	(2)	(3)	(4)
lcl	0.147**	0.134**	−0.022	−0.016
	(2.32)	(2.39)	(-1.49)	(-1.09)
lcl × *lnincome*	0.002	0.003	0.003***	0.002***
	(0.52)	(1.13)	(3.18)	(2.85)
lcl × *traditioncar*	−0.007***	−0.007***	−0.006***	−0.006***
	(-3.07)	(-2.81)	(-6.73)	(-7.33)
Controls	NO	YES	NO	YES
Province FE	YES	YES	YES	YES
F − value	63.765	55.950	63.765	55.950
Observations	1850	1807	1850	1807
R − squared	0.035	0.067	0.073	0.082

7. Conclusions and policy implications

This paper examines the impact of carbon literacy on individuals' intentions and behaviors regarding low carbon consumption of the purchase of new energy vehicles. We employ the IV strategy to identify causal effects and find that carbon literacy exerts a positive and significant impact on individual purchase intention, while not on behaviors. Every 1 point increases in carbon literacy scores increases individual purchase intentions by 0.224 which is significant at the 1% significance level. Our analysis also delves into the components of carbon literacy, identifying carbon habit as the most influential, followed by carbon affection and carbon knowledge. Furthermore, we explore regional, educational, and industry-level heterogeneity and subject the findings to robustness tests, affirming the paper's results' solidity. Lastly, we discuss how switching costs contribute to the gap between carbon literacy and behavior, pinpointing income constraints and transition costs as crucial factors.

Although our study identifies the significant role of switching costs in bridging the gap between carbon literacy and low-carbon behaviors, it does not quantify residents' willingness to pay (WTP) for the switch to low-carbon behaviors. Future research could estimate the WTP for low-carbon behaviors, enabling policies to more effectively help residents overcome switching costs and enhance demand-side emission reduction efforts. Additionally, since this study relies on cross-sectional data, future research could extend to panel data to track individual behavioral switching over time. The panel analysis would allow for a more precise analysis of the explanatory factors influencing these switching.

The paper's implications for household-level emission reduction behaviors are significant. Firstly, while carbon literacy positively impacts intentions, its effect on actual behavior is limited. Nonetheless, enhancing carbon literacy remains pertinent, particularly for garnering public support for major low carbon policies. Integrating carbon education into the national curriculum can aid in this endeavor. Secondly, addressing switching costs is essential to bridging the gap between carbon literacy and behavior. Income constraints necessitate policies that alleviate financial barriers to low carbon behaviors, such as incentives, subsidies, and guidance. Meanwhile, enhancing the appeal of low carbon products can mitigate transition costs, thereby encouraging consumer adoption. Lastly, in promoting demand-side emissions reduction within households, it is crucial to consider the heterogeneity of different population groups. In the early stages of advancing voluntary demand-side emissions reductions, priority should be given to residents with higher educational levels, those engaged in secondary and tertiary industries, and those in the eastern and central regions. For residents with lower educational levels, those working in primary industries, and those in the western regions, emphasis should be placed on public awareness campaigns and education to enhance carbon literacy, while also providing economic support to facilitate their transition to low-carbon behavior.

CRediT authorship contribution statement

Yang Liu: Writing – original draft, Methodology, Investigation, Data curation, Conceptualization. **Yugang Yang:** Writing – original draft, Visualization, Methodology, Investigation, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

All errors and omissions remain the sole responsibility of the authors. Financial support from the National Natural Science Foundation of China (No. 72101254 and No. 72141308) and the Research Funds of Renmin University of China (24XNF060 and 17XNS001) is gratefully acknowledged.

Appendix

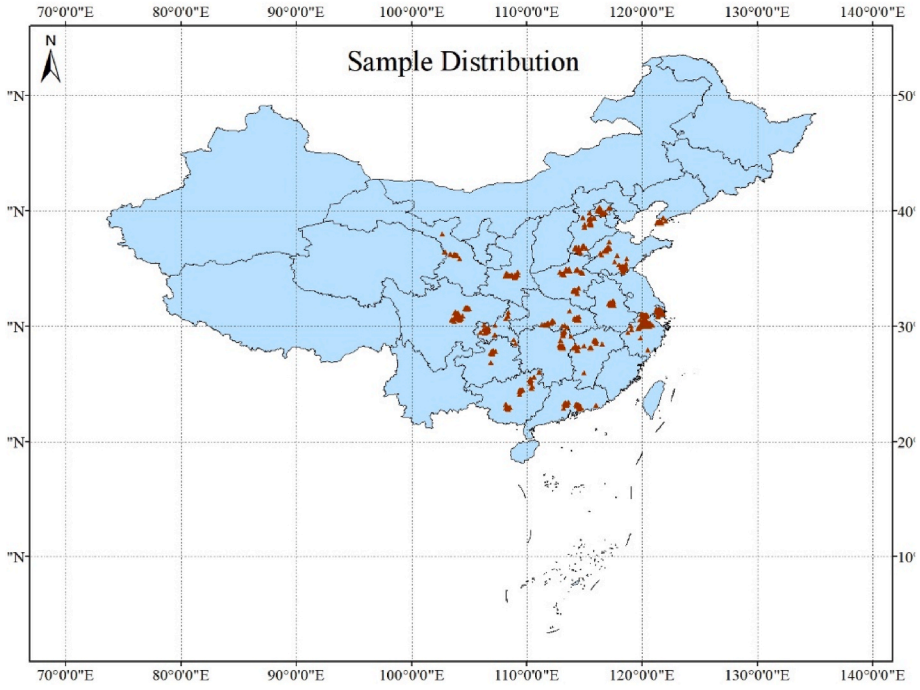

Fig. A.1. The regional distribution of the sample.

Fig. A.2. Carbon literacy in different regions.

Table A.1
Cronbach's Alpha of Indicators

Indicator	Cronbach's Alpha	Indicator	Cronbach's Alpha	Indicator	Cronbach's Alpha
All Indicators	0.7538	Drop Indicator 10	0.7383	Drop Indicator 20	0.7452
Drop Indicator 1	0.7372	Drop Indicator 11	0.7519	Drop Indicator 21	0.7477
Drop Indicator 2	0.7542	Drop Indicator 12	0.759	Drop Indicator 22	0.7471
Drop Indicator3	0.7462	Drop Indicator 13	0.7469	Drop Indicator 23	0.7458
Drop Indicator 4	0.7489	Drop Indicator 14	0.736	Drop Indicator 24	0.7497
Drop Indicator 5	0.7545	Drop Indicator 15	0.7479	Drop Indicator 25	0.7481
Drop Indicator 6	0.7347	Drop Indicator 16	0.748	Drop Indicator 26	0.7536
Drop Indicator 7	0.7445	Drop Indicator 17	0.7452	Drop Indicator 27	0.7491
Drop Indicator 8	0.7503	Drop Indicator 18	0.7459	Drop Indicator 28	0.7532
Drop Indicator 9	0.7469	Drop Indicator 19	0.7502	Drop Indicator 29	0.7493

Table A.2
Sample composition comparison

Variable	Our Sample	Seventh census data
male and female		
male	62.92%	51.24%
female	37.08%	48.76%
urban and rural		
rural	36.54%	36.11%
urban	63.46%	63.89%
education composition		
primary school and below	1.78%	24.77%
junior high school	10.70%	34.50%
high school	20.97%	15.10%
three-year college	33.14%	15.47%
undergraduate	31.84%	
Master's degree or higher	1.25%	
ethnic group composition		
Han ethnic	94.70%	91.11%
Other ethnic	5.30%	8.89%
marital status composition		
married	68.49%	72.67%
unmarried	29.46%	19.20%
divorced	1.51%	2.38%
widowed	0.54%	5.74%
Age composition		
<60	81.92%	77.21%
≥ 60	18.08%	22.79%
family size composition		
family mean population	3.58	2.62
2 or less	15.52%	55.08%
3	37.68%	20.99%
4	26.38%	13.17%
5	12.97%	6.17%
6 and above	7.44%	4.59%
Area composition		
the East	44.97%	39.93%
the Middle	29.95%	25.83%
the West	21.84%	27.12%
the Northeast	3.24%	6.98%

Notes: The high school education includes general high school, junior college and vocational high school; The nation's data is from the China Seventh Population Census.

Table A.3
Summary statistics for each subject of carbon literacy

Component	Subcategories	Subject	Mean	Std.Dev
Low Carbon Knowledge (LCK)	Basics (BSK)	BSK1	0.786	0.41
		BSK2	0.5084	0.1764
		BSK3	0.7838	0.1466
		BSK4	0.358	0.48
		BSK5	0.185	0.388
	Consequence Awareness (CSA)	CSA1	0.7	0.458
		CSA2	0.8292	0.1398
		CSA3	0.594	0.491
		CSA4	0.614	0.487
		CSA5	0.834	0.373
	Practical skills (PTS)	PTS1	0.368	0.482

(*continued on next page*)

Table A.3 (*continued*)

Component	Subcategories	Subject	Mean	Std.Dev
		PTS2	0.426	0.495
		PTS3	0.938	0.242
		PTS4	0.743	0.437
		PTS5	0.539	0.499
Low Carbon Affections (LCA)	Values (VAL)	VAL1	4.323	0.588
		VAL2	4.298	0.679
		VAL3	3.439	1.073
	Attitude (ATT)	ATT1	3.875	0.709
		ATT2	3.675	0.99
		ATT3	3.361	0.976
	Self-efficacy (SEF)	SEF1	4.092	0.676
		SEF2	4.245	0.626
Low Carbon Habits (LCH)	Self-type (SLH)	SLH1	3.889	0.78
		SLH2	3.841	0.802
		SLH3	2.918	1.177
	Social Type (SCH)	SCH1	4.164	0.74
		SCH2	3.124	0.953
		SCH3	3.897	0.68

Table A.4
The impact of carbon literacy on intention and behavior in the clothing purchase

	Logit		2SLS	
	intention	behavior	intention	behavior
	(1)	(2)	(3)	(4)
lcl	0.136***	0.094***	0.041**	0.016
	(4.80)	(4.00)	(2.08)	(0.79)
male	−0.066	−0.421***	−0.010	−0.066***
	(-0.35)	(-2.68)	(-0.37)	(-2.64)
rural	−0.315*	−0.441***	−0.044	−0.071***
	(-1.72)	(-3.42)	(-1.63)	(-3.24)
lnincome	0.264	−0.197	0.019	−0.030*
	(1.34)	(-1.39)	(0.89)	(-1.73)
age	−0.040	−0.017	−0.006	−0.003
	(-0.64)	(-0.36)	(-0.71)	(-0.35)
age2	0.000	0.000	0.000	0.000
	(0.52)	(0.24)	(0.59)	(0.24)
famnum	−0.004	−0.060	−0.003	−0.009
	(-0.04)	(-0.87)	(-0.23)	(-0.84)
oldrate	0.516	0.326	0.065	0.049
	(1.11)	(0.85)	(1.10)	(0.84)
childrate	−0.073	0.003	−0.033	−0.004
	(-0.16)	(0.01)	(-0.52)	(-0.05)
party	−0.019	−0.157	−0.027	−0.025
	(-0.07)	(-0.70)	(-0.67)	(-0.69)
belief	0.042	−0.259	0.008	−0.041
	(0.04)	(-0.40)	(0.05)	(-0.36)
race	−0.452	−0.109	−0.071*	−0.016
	(-1.21)	(-0.27)	(-1.71)	(-0.27)
unmarried	0.167	0.027	0.004	0.002
	(0.54)	(0.09)	(0.09)	(0.04)
eduy	−0.073**	−0.020	−0.017**	−0.004
	(-2.41)	(-0.56)	(-2.07)	(-0.44)
Constant	−0.389	3.014	0.339	1.020***
	(-0.16)	(1.52)	(0.87)	(2.94)
Province FE	YES	YES	YES	YES
F value			60.383	74.484
Observations	1446	1807	1446	1807
Pseudo R2	0.085	0.041	0.049	0.041

Notes: The first two columns are the results of the logit regression and the last two columns are results of the IV regression; in the survey, the question of behavior is "Whether or not the respondents do buy low-carbon and environmentally friendly clothes, such as clothes made of bamboo fabrics, socks, and so on, and don't wear fur clothes", which is a binary variable of whether or not respondents have already done so. low-carbon behavior in the field of clothing, which is an action question; the question of intention is "whether it is acceptable for the price of low-carbon clothing to increase", which is also a binary outcome variable. From the OLS and logit regression results, carbon literacy has a significant and positive relationship with intension and behavior, which are significant at the 1% level. However, from the IV regression results, carbon literacy only has a significant and positive effect on intention but not on behavior.

Table A.5
The estimation of IV-Probit

	intentions		behavior	
	(1)	(2)	(3)	4)
lcl	0.268***	0.271***	0.059	0.044
(5.59)	(4.61)	(0.93)	(0.57)	
Controls	No	YES	No	YES
F value	8.61	15.64	8.61	15.64
Province FE	YES	YES	YES	YES
Observations	1850	1807	1850	1807

Notes: Because the IV-Probit model can only be used for binary interpreted variables, we divide the variable "intentions" from five classified variables into two value variables, and select "Very well" and "Partially" to assign the value to 1, and the other values to 0. Z statistics in parentheses. * * *, * *, * represent the significance level of 1%, 5% and 10% respectively.

Data availability

The authors do not have permission to share data.

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