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Original Research

Chinese Consumers' Preference and Willingness to Pay for Carbon-Labeled Forest Fruit Products

Chengjun Wang[1, 2#], Jianyong Zhu[1#], Xu Zhang[1#], Lei Li[1, 2*], Mingtu Wang[3]

[1] College of Economics and Management, Zhejiang A&F University, Hangzhou, China
[2] Research Academy for Rural Revitalization of Zhejiang Province, Zhejiang A&F University, Hangzhou, China
[3] Changshan County Huyou Production and Marketing Industry Association, Quzhou, China

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Abstract:

Carbon labeling of forest fruit products is an important approach to guide consumers toward low-carbon consumption and achieve agricultural carbon neutrality. This study employs a choice experiment method, taking Huyou Pomelo as an example, based on survey data from 1,108 consumers in five cities: Hangzhou, Shanghai, Nanjing, Hefei, and Beijing. This study analyzes consumers' preferences and willingness to pay for carbon-labeled Huyou Pomelo and explores their heterogeneous preferences by utilizing the Random Parameters Logit(RPL) model and the Latent Class Analysis(LCA) model. The results show that: (1) Despite the relatively low public awareness of carbon labeling, customers still have a strong willingness to purchase carbon-labeled products. (2) Consumers have an average willingness to pay 7.772 yuan/kg for carbon-labeled attributes, and a complementary relationship exists between carbon and traceability labeling. (3) Consumer age and marital status significantly influence the preferences of consumers to purchase carbon-labeled Huyou. However, no significant differences exist in purchasing intent based on gender, education level, income level, or household size. Based on the above conclusions, this study provides recommendations for Huyou producers in consumer market segmentation and for the government to improve carbon labeling–related systems.

Keywords: carbon labeling, willingness to pay, consumer preferences, choice experiments, latent class models.

Introduction

Climate change has had a series of impacts on the economy and society, posing severe challenges to human survival and development. As the world's largest developing country and a responsible major power, the Chinese government announced at the 2020 United Nations General Assembly its commitment to strive for a carbon peak before 2030 and achieve carbon neutrality before 2060 (referred to as the "dual carbon" goals). The key to implementing the "dual carbon" goals lies in reducing emissions and increasing carbon sinks. The forestry and fruit industry has a dual role as a carbon sink and carbon source. On the one hand, fruit trees can absorb a significant amount of carbon dioxide through photosynthesis, contributing to carbon sequestration. On the other hand, modern forestry and fruit production often require substantial inputs of

* e-mail: lileicem@zafu.edu.cn(Lei Li)
# Authors contributed equally

agricultural materials, leading to substantial greenhouse gas emissions.

Citrus orchards are one of the most important economic tree plantations globally and the largest category of fruit crops in the world. They hold immense potential in terms of carbon sequestration and enhancing carbon sinks [1]. According to statistics, China's citrus production reached 44.6 million tons in 2021, accounting for almost 28% of the global citrus production [2]. China ranks first in citrus production and cultivation area worldwide [3]. From a production perspective, adopting low-carbon scientific management practices for fruit trees plays a significant role in mitigating the greenhouse effect [4]. Taking citrus as an example, conducting a systematic assessment of carbon emissions throughout the citrus lifecycle and implementing targeted emission reductions can greatly reduce carbon emissions [5]. Examples include reducing the usage of pesticides and fertilizers, simplifying packaging, and shortening transportation distances [6]. These measures are crucial for achieving agricultural carbon neutrality. How can citrus producers be guided toward low-carbon production and achieve the low-carbon transformation and upgrading of the citrus industry?

As an environmental label on consumer goods, carbon labeling aims to communicate the carbon emissions throughout the entire lifecycle of a product, including production, packaging, transportation, sales, consumption, and recycling, through carbon accounting [7]. Carbon labeling guides consumers to choose low-carbon products with low carbon emissions. Promoting carbon labeling allows consumers to gain a deep understanding of the environmental impact of the products they purchase. This label helps consumers develop awareness and habits of low-carbon consumption, which in turn forces businesses to undergo low-carbon transformations. This case, in turn, leads to a reduction in greenhouse gas emissions and helps mitigate climate change. Currently, carbon labeling has been increasingly accepted and promoted by numerous countries or regions, with positive results. However, carbon labeling is predominantly prevalent in developed countries. Research showed that consumers in developed countries have a relatively high level of environmental awareness and a strong willingness to purchase carbon-labeled products [8,9]. A study conducted by the European Environment Agency in 2009 found that 72% of EU citizens support the carbon labeling system and believe that it could be mandatorily enforced [10].

Compared with developed countries, the development of carbon labeling in China has been relatively slower. As early as 2009, the China National Institute of Standardization completed the translation of PAS2050 and initiated carbon labeling pilot projects. After 10 years of exploration, in 2018, the electrical and electronics industry in China took the lead in initiating a pilot program for "carbon footprint labeling." In 2021, Hangzhou city launched the first bamboo shoot carbon label in China called "Tianmushuiguosun." Subsequently, various regions in China gradually introduced carbon labels for different agricultural products. However, carbon labeling for agricultural products, including forest and fruit products, has not made substantial progress. Various types of carbon labels for agricultural products mainly rely on the voluntary participation of businesses and local practices, and a nationwide unified system or standard has not yet been established. Consumer behavior and their acceptance of carbon labeling are indeed key factors in driving the development of carbon-labeled forest and fruit products. Hence, understanding the current level of awareness and acceptance of carbon labeling among Chinese consumers is crucial to further promoting the development of carbon labeling for forest and fruit products.

Many scholars have analyzed Chinese consumers' preferences, willingness to pay (WTP), and influencing factors regarding carbon labeling from various perspectives, methods, and research subjects. From a research methodology perspective, some scholars have employed stated preference methods. For example, Shuai et al. [11] conducted a scenario experiment to analyze consumers' preferences and WTP for agricultural products, such as bananas and eggs, and instant noodles with low, medium, and high carbon labels. Zhao and Zhong [12] combined auction experiments with consumer experiments to observe college students' willingness to purchase and pay for food products with carbon labels. Compared with the revealed preference methods, the stated preference methods are more effective in describing market responses when the products have not yet appeared on the market, which is the case for carbon-labeled products in the Chinese market as they have not yet been widely circulated. The contingent valuation method (CVM) is the most common and widely used stated preference method. Ying et al. [13] examined the WTP among urban Chinese consumers for low-carbon pork and found that they are willing to pay 7.74 yuan/kg for its low-carbon attributes. Moreover, the researchers identified two motivating factors behind consumers' WTP premium for low-carbon attributes, namely, altruistic and self-interest motivations. With the rise of choice experiments, a few scholars started using this method to investigate Chinese consumers' preferences and WTP for low-carbon products. Choice experiments allow for the evaluation of consumer preferences for different product attributes and explore the relationships among those attributes. This approach effectively avoids the limitations of CVM, which can only measure a single attribute of a product. Zhang et al. [14] used the choice experiment to explore the preferences of urban consumers for carbon-labeled milk and analyzed the sources of heterogeneity in their preferences. Additionally, the study examined the interaction between carbon labeling and factors such as fat content and organic certification labels. In terms of research subjects, existing literature mainly focused on analyzing consumers' WTP for carbon-labeled products using pork [13,15] and milk [12,16] as mediums. Research on tree and fruit products is relatively limited. Indeed, these studies contributed to our understanding of Chinese consumers' low-carbon consumption behavior. However, compared with the ongoing progress in the low-carbon

economy, comprehensive research on consumers' low-carbon product consumption behavior is still lacking.

Given the wide variety of citrus fruits, drawing valid conclusions without considering the specific product types is indeed challenging [17]. Therefore, this study focuses on the use of a specific Chinese geographical indication product, Changshan Huyou (a local Chinese brand of Pomelo, abbreviated as "Huyou"), as a medium. The study aims to empirically analyze consumers' preferences and WTP for carbon-labeled forest and fruit products using the choice experiment. This study also aims to address the following questions: First, what is the current level of awareness and attitude among Chinese consumers toward carbon labeling? Second, what is the WTP for different attributes of carbon-labeled products, and what is the relationship among these attributes? Third, what are the differences in purchase motivations and attribute preferences for carbon-labeled forest and fruit products among different consumer groups?

Theoretical Framework

The theoretical research basis of this study is the consumer theory proposed by Lancaster [18] and the random utility theory proposed by McFadden [19]. Lancaster's consumer theory suggests that consumers' preferences are based on the selection of attributes of a product. Specifically, consumers consume not only the product itself but also the attributes associated with it, which can provide them with additional utility. In other words, consumers aim to maximize their utility by making choices based on the attributes of the product, given their inherent budget constraints.

Carbon-labeled products, in addition to the basic utility derived from their regular functionalities, also possess an additional "environmental utility" that satisfies consumers' environmental consciousness and psychological needs [20]. Therefore, the total utility of carbon-labeled Huyou Pomelo can be understood as the sum of functional and environmental utility. The latter represents the additional value of carbon-labeled Huyou Pomelo compared with regular Huyou Pomelo and serves as a key factor for consumers to change their purchasing intentions and willingness. Existing literature on consumers' purchasing intentions and influencing factors of carbon-labeled products mainly included three aspects: consumers' demographic characteristics, consumers' low-carbon awareness and attitudes, and product attribute features. The first two aspects primarily influence the environmental utility of carbon-labeled products, that is, whether consumers are willing to pay a premium for the environmental utility of the product, which is closely related to consumers' demographic characteristics and low-carbon awareness and attitudes. From another aspect, product attributes reflect consumers' WTP a premium for the functional utility of the product.

In terms of demographic characteristics, existing research analyzed consumers' preferences and WTP for carbon-labeled products based on gender, age, education level, household income, family size, and other variables [21-23]. However, the results are not consistent and sometimes even contradictory. The consensus is that consumers with high income and education levels are likely to pay a high price for carbon-labeled products [24,25]. However, Duan et al. [26] concluded that consumers with different incomes and educational levels do not show significant differences in their willingness to purchase carbon-labeled products. Similarly, Shuai et al. [11] and Wong et al. [27] found that male consumers in China are more willing to purchase carbon-labeled products and pay a higher premium, whereas Liang et al. [28] found that female consumers are more willing to accept low-carbon products. Therefore, further research is needed to understand the impact of demographic characteristics on preferences and purchasing intentions toward carbon-labeled products.

Consumer cognition and attitudes include cognition and attitudes toward carbon labels and environmental protection. A study conducted in the UK indicated that 89% of the respondents were confused about the concept of carbon labels [29]. The main reason is the relatively short development time of carbon labels globally and the difficulty for consumers to differentiate among the various types and standards. Therefore, when consumers lack an understanding of carbon footprints and climate-friendly food, engaging in low-carbon purchasing behavior becomes challenging for them [29,30]. This viewpoint is supported by Emberger et al. [31] through information provision. In contrast to the concept of carbon labels, the low-carbon concept is more familiar to consumers. Studies found that consumers who are environmentally conscious and concerned about ecology, overall benefits, and social responsibility are willing to pay an extra cost to purchase environmentally friendly food [32,33]. Xing et al. [33] further discovered that consumers' motivation to pay a premium for the low-carbon attributes of food comes from both altruistic and self-interest aspects. When consumers' main motivation for purchasing is not environmental protection but their health and safety, their willingness to purchase carbon-labeled products significantly decreases.

In terms of product attribute features, Feldmann et al. [34] found that consumers are willing to pay a premium for products that display additional information. Apart from carbon labels, other attribute labels of the product, such as organic, fair trade, animal welfare, and other information labels, can also influence consumers' willingness to purchase carbon-labeled products [22]. Akaichi et al. [35] found that consumers in France, the Netherlands, and the UK are willing to pay more for bananas that have carbon, fair trade, and organic labels simultaneously rather than individually. Of course, a single product cannot possess all product attributes, and complementarity or substitution relationships may exist among different attributes. Bond et al. [36] found that organic food and nutritional labels are complementary. Meas et al. [37] found a substitution relationship between organic and local food labels, whereas Gracia et al. [38] suggested that they may have a complementary relationship. However, the latter did not provide direct evidence and argued that the relationship between organic and local food labels depends on the

product and the country, requiring further assessment for specific products and target populations.

Furthermore, nutrition and traceability labels are also important determinants that consumers consider when purchasing products [17,39,40]. The food traceability system is considered one of the primary tools to fundamentally prevent food safety risks [41]. Existing research showed that the food traceability system can restore consumer confidence by increasing trust, and therefore, consumers are willing to pay for traceability labels [42-44]. However, Wu et al. [45] found through a survey conducted in Jiangsu Province, China, that although most Chinese consumers are concerned about food safety, their WTP premium for traceability labels is low, which may be related to income and cognitive levels. With the development of the economy and improvement of living standards, consumers are increasingly focusing on the nutritional properties related to health in addition to considering food safety [46-48]. These studies demonstrated consumers' WTP a premium for nutritional claims on food products.

To summarize, consumers' demographic characteristics, low-carbon awareness and attitudes, and product attribute features may influence their willingness to purchase carbon-labeled Huyou Pomelo. However, considering the differences in consumer culture and national conditions, consumers in different countries may vary in their emphasis on and preferences for different attributes of food. Fundamentally, consumer preferences and purchasing behavior are primarily driven by considerations of environmental protection, food safety, and personal health. Moreover, carbon, traceability, and nutrition labels happen to represent these three attributes (Figure 1). Despite the existence of studies internationally using choice experiments to investigate consumer preferences and WTP for carbon labels, few studies have explored these three representative attributes together on the same product. Moreover, research on consumers' WTP for citrus fruits is limited. Therefore, this study uses Huyou as a medium and employs a choice experiment to empirically analyze consumers' preferences and WTP for different attributes of carbon-labeled Huyou Pomelo. This study aims to provide some market guidance for low-carbon agricultural production and contribute to the improvement of China's carbon labeling system by further segmenting consumers through latent class modeling. Compared with similar studies, this research makes valuable explorations in terms of research content and research subjects.

Materials and Methods

Choice Experiment

As a tool to measure consumer preferences for different attributes and prices of products or services, the choice experiment is widely used in the fields of agricultural and food economics. This study selects choice experiment for analysis because of the following several reasons: 1. Choice experiment can simulate real choice scenarios and evaluate hypothetical goods that do not exist in the market or goods that have not been traded yet, such as carbon-labeled citrus fruits, which are not currently available in the market. 2. This tool can evaluate products or services with multiple attribute levels simultaneously. In this study, Huyou is composed of three attributes: carbon, traceability, and nutrition labeling. 3. Choice experiment provides high efficiency in data collection with relatively low costs.

Product Attributes and Level Settings

Based on the literature review and interviews with relevant field experts, this study selects "price," "carbon labeling," "traceability labeling," and "nutrition labeling" as attribute variables (Table 1). Regarding the price attribute, the average price of Huyou is calculated as 8 yuan/kg based on statistical data from the government's agricultural department's work report in 2022. This price is then adjusted with fluctuations. Combining existing research on the price premium levels of carbon-labeled products and through comparisons with prices on e-commerce platforms, supermarkets, and fruit shops, the price levels are set at 5, 10, 15, and 20 yuan per kilogram, which broadly cover the Huyou prices in the

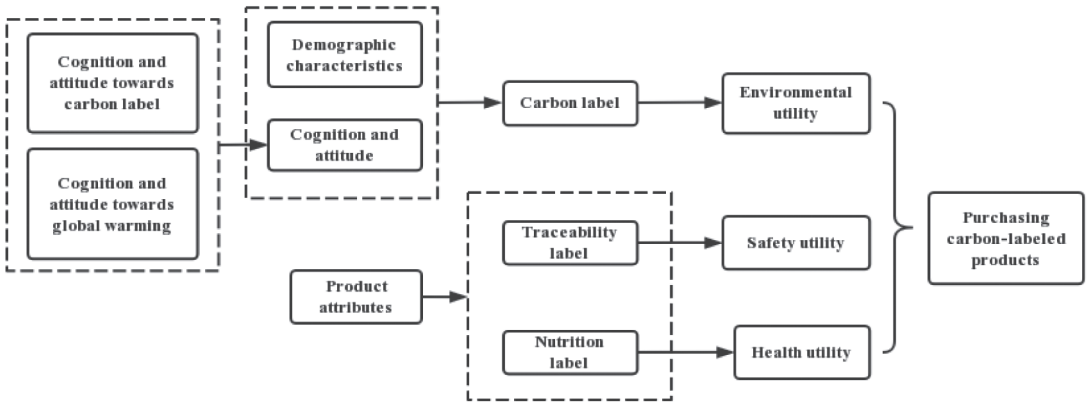

Fig. 1. Theoretical model of purchasing carbon-labeled products.

Table 1. Attribute and attribute levels used in the choice experiment

Attributes	Attribute levels
Price (yuan/kg)	5, 10, 15, 20 yuan/kg
Carbon label	With carbon label, without carbon label
Traceability label	With traceability code, without traceability code
Nutrition label	With nutrition label, without nutrition label

Chinese market. The carbon labeling attribute is presented in the form of images that display the carbon emissions associated with the entire life cycle of the Huyou. These figures are calculated by a professional team from China Agricultural University. The attribute has two levels: "with carbon labeling" and "without carbon labeling." The traceability labeling attribute is presented in the form of a "Zheshilian" traceability QR code. This system is currently used by approximately 390,000 merchants. The attribute has two levels: "with traceability code" and "without traceability code." The nutrition labeling attribute represents the nutritional composition of the Huyou and is also presented in the form of images, indicating several common nutritional elements. The attribute has two levels: "with nutrition labeling" and "without nutrition labeling."

Determination of Choice Sets

According to the attribute and level settings in Table 1, a full factorial design would generate 32 hypothetical profiles, resulting in 992 different choices for consumers. However, respondents may experience decision fatigue and reduced efficiency after evaluating approximately 15–20 profiles [49]. This study adopts a fractional factorial design to create eight sets of choices with higher efficiency using Stata to facilitate respondent answers and mitigate fatigue. As shown in Figure 2, these choice sets are presented in image format, with each set consisting of three options. Among them, nutrition labeling is represented by nutrient content that contains the common nutrients energy, protein, fat, carbohydrate, vitamin, amino acid, P, K, and Fe. Traceability labeling is represented by trace code, and carbon labeling is designed by local government departments and related institutions. Respondents are asked to select their preferred option from each choice set, including the option of "not purchasing", to make the choices realistic to actual buying situations [50].

Questionnaire Design

The questionnaire consists of three parts: 1. The first part assesses consumer awareness and consumption of carbon-labeled products. 2. The second part involves the choice sets, where respondents are presented with the sets of options generated from the fractional factorial design mentioned earlier. 3. The third part collects demographic information about the respondents, including gender, household size and composition, age, educational level, and income level. In addition, before responding to the choice sets in the second part, participants are requested to read a cheap talk [51]. The cheap talk explains the issue of hypothetical bias to the respondents, reminding them of budget constraints, and asks them to respond as they would in real-life situations.

Following the approach of Gao et al. [52], we have included three types of trap questions in the questionnaire to ensure data reliability and improve questionnaire quality: 1. The first type is "impossible to answer questions." This type of question includes options that are impossible or logically inconsistent. We can assess the seriousness of their responses and identify invalid questionnaires by observing whether respondents select these impossible options. 2. The second type is "designated answer options." In these questions, respondents are explicitly instructed to choose a specific option. If respondents fail to select the instructed option, then the respondent may lack attentiveness while answering the questionnaire. 3. The third type is "repeated questions." Taking advantage of the online questionnaire format, a randomly repeated choice set appears in the choice set section, and consistency between the initial and repeated responses is checked. This process helps

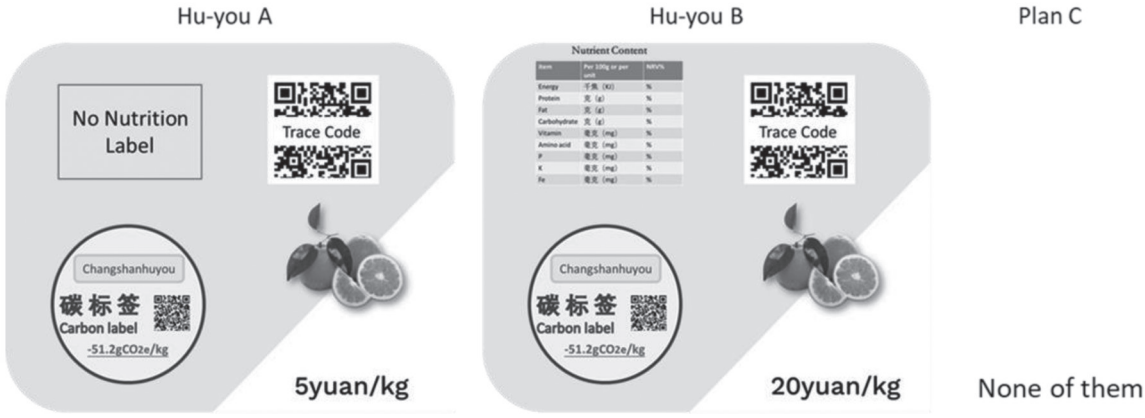

Fig. 2 Sample choice set.

determine whether respondents are providing consistent answers throughout the questionnaire. These three methods significantly contribute to assessing the sincerity of respondents' answers and enable the removal of invalid questionnaires from the dataset.

Data Collection

This study is based on online survey data collected from five major cities in China (Hangzhou, Nanjing, Shanghai, Hefei, and Beijing) from April to May 2023. The selection of these five cities is based on two main reasons: 1. Huyou pomelo is mainly produced in Quzhou City, Zhejiang Province, which is located in the Yangtze River Delta Economic Zone. Hangzhou, Nanjing, Shanghai, and Hefei are important cities within this economic zone and serve as major sales areas for Huyou. Consumers in these cities have a deep understanding of Huyou. Beijing, from another aspect, is a significant distribution center for agricultural products in China and provides insights into the market for Huyou Pomelo. 2. All five cities are economically developed and have high Internet penetration rates, making them suitable for targeting online respondents. Additionally, this time period coincides with the season when Huyou is available in the market, which helps to capture authentic consumer choices.

The online surveys in this study were collected through "Wenjuanxing" (www.wjx.cn). Wenjuanxing is one of the largest and most popular survey providers in China, with a wide range of sample sources covering various age groups, occupations, and income levels of consumer groups nationwide. Wenjuanxing has been widely used in consumer preference research. Online surveys are increasingly popular because of their low cost, rapid response, broad coverage, and professional advantages in facilitating response [53]. In addition to setting trap questions, we implemented additional screening measures, such as IP address limitation, age restrictions and time limitations for answering each scenario question, to further enhance the quality of the questionnaire. After excluding invalid questionnaires, a total of 1108 valid questionnaires were obtained, with roughly equal sample sizes from the five cities.

Table 2 describes the assignment and distribution characteristics of consumer personal demographic variables. Among all respondents, females account for 58.5%, slightly more than males. Over 60% of the respondents are married, with an average age of around 31 years. The overall educational level of the respondents is at the college or above level, indicating a relatively high level of education. Nearly half of the households have a monthly income of over 17,000 yuan, which is related to the high level of economic development in the surveyed areas.

Table 2. Demographic characteristics of the sample (n = 1108)

Categories	Variable names	Description	Mean	SD
Personal characteristics of consumers	Gender	1: Male; 0: Female	0.415	0.493
	Age	Actual age (year)	31.11	8.247
	Marriage	1: Married; 0: Unmarried	0.606	0.489
	Education	6: Primary school; 9: Junior school; 12: Senior school; 15: junior college; 16: Bachelor's; 18: Master's or above	15.79	1.354
	Monthly family income	1: ¥3000 or below; 2: ¥3001–¥5000; 3: ¥5001–8000; 4: ¥8001–11000; 5: ¥11001–14000; 6: ¥14001–17000; 7: ¥17000–20000; 8: ¥20001-30000; 9: ¥30001–50000; 10: ¥50001 or above	5.976	2.417
	Family size	1;2;3;4;5 or above	3.204	1.110
	Children aged 16 or below	1;2;3;4;5 or above	0.665	0.654
	Elders aged 65 or above	1;2;3;4;5 or above	0.404	0.719
Cognition and Attitude	Cognition of carbon label	1: Never heard of; 2: Heard of it but not strongly understanding; 3: Heard of it and basic understanding; 4: Know better; 5: Strongly understanding	2.463	1.033
	Cognition of serious global warming issue	1: Strongly Disagree; 2: Disagree; 3: General or not known; 4: Agree 5: Strongly Agree	4.365	0.692
	Attitude toward carbon label	1: Strongly not supporting; 2: Not supporting; 3: Possibly supporting; 4: Supporting; 5: Strongly supporting	4.094	0.775
	Attitude toward global warming	There are 3 true/false statements in total. (correct = 1; wrong = 0)	2.727	0.554

Notes: As following are three statements about attitude to global warming.
a. I carry my own shopping bag when shopping. b. When I turn on the air conditioner in summer, I will keep the temperature around 26 degrees. (Tips: In summer, the human body is most comfortable and saves electricity when the air conditioning temperature is 26-28 degrees.) c. I try to buy energy-saving household appliances.

Three-member and four-member families are the dominant household sizes, with slightly more for three-member families, which is consistent with the basic family structure in China. In terms of awareness and attitudes toward global warming, the scores are 4.365 and 2.727, respectively. This result indicates that the majority of consumers are aware of the significant impact of global climate change on the environment and human habitats, and they have a high level of acceptance of low-carbon lifestyles. The scores for carbon label awareness and support are 2.463 and 4.094, respectively, suggesting that consumers have limited awareness of carbon labels. However, most of them support the development of carbon labels.

Econometric Models

This study is based on random utility theory and employs a Random Parameters Logit (RPL) model and a Latent Class Analysis (LCA) model to construct and estimate models using the stated preference data collected from choice experiments.

The random utility theory assumes that consumers are heterogeneous. In this study, if J combinations of Huyou schemes exist in choice set C, then the utility of consumer n choosing the i-th Huyou scheme from the J subset in scenario t can be represented as follows:

$$U_{nit} = V_{nit} + \varepsilon_{nit}. \quad (1)$$

In the equation, V_{nit} represents the observable consumer utility information, where $V_{nit} = \beta X_{nit}$, β is the utility weight vector, representing individual preferences. The random term is the attribute vector of the i-th Huyou scheme chosen by consumer n in scenario t. ε_{nit} represents the unobservable part.

For rational individuals, people always make choices that maximize their utility. When a consumer chooses the i-th Huyou scheme, the utility of that Huyou scheme is greater than the other Huyou schemes within the same J subset based on the condition. The specific expression of this condition can be represented in Eq. (2) as follows:

$$P_{nit} = prob(U_{nit} > U_{nkt}) = prob(V_{nit} + \varepsilon_{nit} > V_{nkt} + \varepsilon_{nit}) \; \forall i \neq k, i \in J, k \in J \quad (2)$$

In terms of model selection, the random parameters logit model, also known as the mixed logit model, is often applied in choice experiment analysis. This model is capable of capturing the heterogeneity in individual preferences among respondents by allowing the coefficients β of various attribute levels to randomly vary across consumers. Therefore, f(β) represents the probability density of β. Moreover, the unconditional probability of a consumer choosing the i-th Huyou option can be obtained as shown in Eq. (3) by integrating all possible values of β. Furthermore, maximum likelihood estimation can be used to estimate the coefficients of each attribute level.

$$\bar{P}_{nit} = \int \frac{\exp(V_{nit})}{\sum_j \exp(V_{njt})} f(\beta|\theta) d\beta. \quad (3)$$

The RPL model assumes that the preferences and characteristics of each respondent are different, which makes it more precise but computationally complex. From another aspect, the LCA model relaxes this assumption and considers heterogeneity among individuals while assuming homogeneity within each class, yielding potentially high informative results [54]. Thus, we can choose the LCA model to classify the N individuals into S classes, where each class consists of homogeneous consumers. In the case of the choice-based logit model, f(β) becomes discrete. The probability of a consumer choosing option i under condition T in the classified logit model can be represented as follows:

$$P_{nit} = \sum_{s=1}^{s} \frac{\exp(\beta_s X_{nit})}{\sum_j \exp(\beta_s X_{njt})} R_{ns}. \quad (4)$$

Among them, β_s represents the parameter vector corresponding to the consumer group of class S, and R_{ns} is the probability of consumer n belonging to class S. This probability can be represented as follows:

$$R_{ns} = \frac{\exp(\theta_s Z_n)}{\sum_r \exp(\theta_r Z_n)}. \quad (5)$$

In the given context, Zn represents the individual characteristic variables that influence consumer i in class S, and represents the parameter vector of consumers in class S.

The utility level of product attributes is often reflected through WTP. Hence, the preference testing of consumers for product attributes can, to some extent, be translated into a comparison of WTP for each attribute [55]. After estimating the attribute parameters through the random utility model and LCM, the WTP for different attributes can be further calculated using the following formula:

$$WTP_i = -\beta_i / \beta_p. \quad (6)$$

In the equation, θ_s represents the WTP for the i-th attribute level by the consumer. β_i and β_p are the estimated coefficients for the attribute level variable and price, respectively.

Results and Discussion

Consumer Preferences and WTP for Different Attributes of Huyou Pomelo

The random parameters logit model estimation was conducted using Stata 16 software, and Table 3 shows the results. From Model 1, the overall goodness-of-fit of the model is good, with all coefficient estimates being statistically significant at the 1% level and having signs consistent with the expected empirics. Specifically, the coefficient for the price variable is statistically significant and negative, indicating that consumers tend to choose Huyou with lower prices, which aligns with consumer demand theory. The coefficient estimation for the "None" option is significantly negative, indicating that respondents are inclined to make a choice among the presented Huyou options in the choice experiment rather than choosing to

Table 3. Consumers' preferences for different attributes of huyou

	Model 1 without interactions		Model 2 with interactions	
	Mean	SD	Mean	SD
Carbon label	1.118***	1.236***	0.721***	1.298***
	(0.054)	(0.060)	(0.119)	(0.066)
Traceability label	0.312***	0.993***	−0.029	1.027***
	(0.049)	(0.059)	(0.116)	(0.065)
Nutrition label	1.425***	1.151***	1.363***	1.214***
	(0.057)	(0.058)	(0.117)	(0.064)
Price	−0.144***		−0.151***	
	(0.004)		(0.005)	
None	−2.102***		−2.414***	
	(0.069)		(0.099)	
Carbon label* nutrition label			0.241 (0.196)	0.679*** (0.158)
Carbon label* traceability label			0.695*** (0.201)	0.834*** (0.158)
Log likelihood =	−5878.13		−5857.847	
Chi-square value	892.83		927.70	
Number of obs	26592.000		26592.000	

Note: Standard errors in parentheses; $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 4. Consumers' willingness to pay for different attributes of Huyou

Attributes	Carbon label	Traceability label	Nutrition label
WTP	7.772	2.167	9.903
	[6.991, 8.552]	[1.491, 2.843]	[9.097, 10.710]

Note: WTP is measured in yuan/kg; the values within parentheses represent the 95% confidence interval for willingness to pay.

abstain, thereby confirming the validity of the experiment. The estimated standard deviations are also significant, confirming the presence of heterogeneous preferences among consumers for the carbon-labeled Huyou and supporting the correctness of the model selection.

The preference coefficients for the carbon labeling attribute, traceability labeling attribute, and nutrition labeling attribute of Huyou products are all statistically significant at the 1% level and positive. This result indicates that consumers have a positive preference for these three attributes. Based on the estimated preference coefficients, the coefficient for the nutrition labeling attribute is the highest (1.425), followed by the carbon labeling attribute (1.118) and the traceability labeling attribute (0.312). This result suggests that consumers have the highest preference for the nutrition labeling attribute, followed by the carbon labeling attribute, and then the traceability labeling attribute.

Additionally, based on the estimation results of the random parameters logit model, this study further utilizes the Delta method to estimate consumers' WTP for the carbon labeling, traceability labeling, and nutrition labeling attributes of Huyou, along with their corresponding confidence intervals [56]. Table 4 shows the results. The estimated WTP for the carbon labeling attribute is 7.772 yuan/kg, indicating that consumers are willing to pay an additional 7.772 yuan/kg to purchase Huyou with the carbon labeling attribute. Compared with the average market price of 8 yuan/kg for Huyou, this case represents a premium rate of 97.15%, which aligns with the expected market price for Huyou. Furthermore, the estimated WTP for the traceability attribute and the nutrition attribute are 2.167 and 9.903 yuan/kg, respectively. Thus, relative to the environmental and safety benefits associated with the carbon labeling and traceability labeling attributes, consumers are most concerned about the nutritional value when purchasing Huyou. Model 2 presents the estimation results after incorporating interaction terms, and the main coefficients and significance levels are consistent with Model 1. Notably, the interaction term between the traceability labeling and carbon labeling attributes is statistically significant and positive. This case suggests a significant interaction effect between traceability and carbon labeling, indicating that including traceability labeling in the Huyou packaging can enhance the overall utility of the carbon-labeled Huyou Pomelo.

The impact of consumers' demographics, cognition, and attitudes on carbon label attribute preferences

This study includes interaction terms between personal characteristics and cognitive and attitudinal factors in the random parameters logit model to further explore the preference differences among consumers with different personal characteristics, perceptions, and

Table 5. The impact of consumers' demographics, cognition, and attitudes on carbon label attribute preferences

VARIABLES	Mean	SD
Carbon label	0.846***	1.162***
	(0.108)	(0.059)
Traceability label	0.319***	1.000***
	(0.049)	(0.059)
Nutrition label	1.422***	1.158***
	(0.057)	(0.058)
Price	-0.289***	
	(0.009)	
None	-2.111***	
	(0.069)	
Carbon label*age	-0.025***	
	(0.007)	
Carbon label*marriage	0.453***	
	(0.144)	
Carbon label*attitude towards serious global warming issue	0.186**	
	(0.092)	
Carbon label*cognition towards carbon label	0.221***	
	(0.056)	
Carbon label*attitude towards carbon label	0.247***	
	(0.069)	
Number of observations	26592	

Note: Standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; The interaction variables have been standardized.

attitudes toward environmental issues. Gender, education level, household income, family size, and cognitive and attitudinal factors toward environmental issues were found to be non-significant in interaction with the carbon labeling attribute. Therefore, this section only includes age, marital status, and cognitive and attitudinal factors toward carbon labeling in interaction with the carbon labeling attribute. As shown in Table 5, the interaction effect between carbon labeling and age is statistically significant and negative, whereas the interaction effect between carbon labeling and marital status is statistically significant and positive. This result suggests that younger or married consumers are inclined to purchase Huyou with carbon labels. One possible reason is that young people are more likely to accept new ideas, whereas married families tend to prioritize their quality of life, making them willing to support low-carbon products. Regarding the cognitive and attitudinal aspects, the attitude towards global warming as well as the cognitive and attitudinal variables toward carbon labeling and their interaction with the carbon labeling attribute are statistically significant and positive. This result indicates that consumers who have a great understanding of carbon labeling and hold positive attitudes toward it are supportive of the development of carbon labeling and environmental protection, and they are willing to pay for products with carbon labels.

Consumer Segments

The LCA model assumes that different consumer segments have heterogeneous preferences for Huyou attributes, which are represented by discrete distribution patterns. Respondents can be classified into different segments by applying the LCA model. The number of segments is usually determined based on the model's Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) values. The number of segments corresponding to the lowest BIC value is selected as the optimal number of latent classes (Appendix Table A1). The results of the LCA model can reveal differences in preference and basic personal attributes among different segments of respondents. The goodness-of-fit indices suggest that the BIC reaches its minimum at five segments, and the AIC also tends to converge at five segments. Therefore, this study chooses to divide the sample into five latent segments. In addition, personal characteristic variables are included as covariates to determine the differences in the probabilities of consumers with different personal characteristics falling into each latent segment.

As shown in Table 6, the sample can be roughly divided into five classes based on consumer demographic characteristics, with each class demonstrating different levels of significance for their attributes, indicating strong heterogeneity. Except for Classes 3 and 4, the price coefficients are negative and significant at the 1% level, suggesting that the majority of respondents' choices align with economic principles, where low prices of Huyou result in great utility [17]. Looking at the three labeling attributes, consumers in Class 1 do not show a preference for carbon, traceability, or nutrition labeling. By contrast, consumers in Class 2 exhibit a strong preference for all three labeling attributes, with significant positive coefficients at the 1% level. Classes 3 and 4 are not sensitive to price but differ in their preferences, with Class 3 favoring traceability labeling and Class 4 favoring carbon and nutrition labeling. In Class 5, all three attribute coefficients are significant, but the coefficient for traceability labeling is negative, suggesting a lack of trust or interest in traceability labeling among these consumers.

Based on the analysis combined with consumer demographic characteristics, using Class 5 as the reference group, we can define the following categories: Class 1: "Price-sensitive" consumers. Typically, they are older individuals who have heard of carbon labeling but have a limited understanding of its meaning. Class 2: "High-quality-oriented" consumers. This category may consist of younger individuals with moderate income levels. They have a high acceptance of carbon labeling and do not have children under the age of 16 to support. Class 3: "Traceability-label-oriented" consumers. This group only has a strong preference for traceability labeling rather than carbon labeling or nutrition labeling. Class 4: "Carbon-label and nutrition-label-oriented" consumers. Classes 4 and 5 belong to this category. Class

Table 6. Five-class regression results from latent class models

VARIABLES	Class 1	Class 2	Class 3	Class 4	Class 5
Price	-0.691***	-0.286***	0.0690***	0.00684	-0.414***
	(0.0484)	(0.0303)	(0.0231)	(0.0336)	(0.0150)
Carbon label	-0.214	0.850***	0.0293	2.938***	0.767***
	(0.206)	(0.136)	(0.115)	(0.200)	(0.0673)
Traceability label	-0.211	0.722***	1.312***	-0.189	-0.195**
	(0.208)	(0.129)	(0.132)	(0.171)	(0.0787)
Nutrition label	0.0166	2.890***	0.127	0.875***	1.068***
	(0.221)	(0.198)	(0.128)	(0.183)	(0.0903)
Gender	-0.136	-0.0393	0.0638	-0.205	
	(0.372)	(0.178)	(0.269)	(0.216)	
Age	0.0511**	-0.0274*	0.0249	-0.0118	
	(0.0207)	(0.0143)	(0.0188)	(0.0167)	
Marriage	-0.481	0.306	0.379	0.899***	
	(0.511)	(0.262)	(0.417)	(0.334)	
Education	0.00904	0.0570	-0.0311	-0.0404	
	(0.135)	(0.0699)	(0.0932)	(0.0822)	
Monthly family income	-0.154	-0.0722*	-0.115*	-0.152***	
	(0.100)	(0.0431)	(0.0696)	(0.0552)	
Family size	0.0712	0.273**	0.137	0.0609	
	(0.217)	(0.107)	(0.197)	(0.145)	
Child under 16	0.364	-0.464**	0.429	-0.0904	
	(0.368)	(0.195)	(0.277)	(0.233)	
Aged over 65	0.0187	-0.137	-0.00485	0.0816	
	(0.273)	(0.145)	(0.219)	(0.179)	
Cognition of carbon label	0.386*	0.120	0.172	0.428***	
	(0.210)	(0.0995)	(0.147)	(0.116)	
Cognition of serious global warming issue	0.213	0.184	0.0147	0.211	
	(0.226)	(0.136)	(0.193)	(0.168)	
Attitude toward carbon label	-0.186	0.233*	0.218	0.453***	
	(0.282)	(0.130)	(0.199)	(0.166)	
Attitude toward global warming	0.243	0.0560	-0.365	0.177	
	(0.378)	(0.159)	(0.232)	(0.232)	
Constant	-4.944*	-2.662**	-2.643	-4.101**	
	(2.674)	(1.354)	(1.829)	(1.644)	
None	-2.682***				
	(0.0820)				
Log likelihood	−5227.205				
Number of obs	26,592				
Class share	4.8%	33.3%	8.2%	15%	38.7%

Note(s): Standard errors in parentheses; $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$; Class 5 is computed as the reference class.

4 primarily consists of married individuals with low to moderate incomes who have a great understanding of carbon labeling and support its implementation. The sample percentages for these five classes are 4.8%, 33.3%, 8.2%, 15%, and 38.7%, respectively.

Overall, gender and education level have no significant influence on consumers' preferences for carbon-labeled Huyou, which is similar to the findings of Duan et al. [26]. Notably, older individuals tend to prefer lower-priced Huyou products. Married or younger families (Classes 2 and 4, accounting for 48.3% of the sample) place a high emphasis on various attributes of Huyou and seek high-quality, high-value products. These findings provide direction for producers to segment the Huyou market.

Conclusions and Implications

The present study utilizes choice experiment data from 1,108 Chinese consumers to analyze the preferences and WTP for carbon-labeled Huyou based on different individual characteristics. The study employs the RPL and LCA models to analyze the data. In the theoretical

framework, this study is the first to incorporate carbon, traceability, and nutritional labels into the same analysis framework. This study explores the differences in utility for consumers when purchasing carbon-labeled Huyou from the perspectives of environmental, safety, and health utility corresponding to the label attributes. The study also examines the underlying relationships among these attributes, leading to the following key findings:

First, Chinese consumers currently have limited awareness of carbon labels, but a majority of consumers support the development of carbon labeling. Second, consumers are willing to pay a premium for the carbon, traceability, and nutritional label attributes of Huyou Pomelo. The WTP for the carbon label attribute is 7.772 yuan/kg, with a premium rate of 97.15%. Additionally, a complementary relationship exists between carbon and traceability labels. When both carbon and traceability labels are present, consumers' WTP for carbon-labeled Huyou significantly increases. Third, individual characteristics can partially explain consumers' heterogeneous preferences. Younger or married consumers have a high preference for carbon-labeled products. These findings provide important insights for producers and policymakers to understand consumer preferences and make informed decisions regarding the development and labeling of carbon-labeled Huyou.

The above research findings provide some implications for Huyou producers and the government. For Huyou producers, it is crucial to start with consumer preferences, accurately understanding their preferences and needs, and using them as a foundation for product development and marketing. Secondly, market segmentation based on consumer age and marital status should be conducted to provide customized marketing strategies and product features for different consumer groups. For instance, developing differentiated pricing strategies based on the price sensitivity of different consumer groups can attract price-sensitive elderly consumers. Additionally, utilizing e-commerce platforms to promote the value of carbon labels is essential, conveying the importance and value of carbon labels to consumers. For the government, the immediate priority is to accelerate the establishment of the carbon labeling system, by promoting the development of unified certification standards for carbon labeling of forest fruit products. Secondly, encourage business participation in carbon label certification and provide support and incentives. Lastly, increase publicity and promotion of the carbon labeling system to enhance consumer awareness and understanding of carbon labels. Additionally, innovate the dissemination of carbon label knowledge to improve consumer recognition and acceptance of carbon labels.

It is anticipated that carbon labeling certification holds promising market potential in the future. Nevertheless, we acknowledge three key limitations in this study. Firstly, there is a possibility of overestimating the Willingness to Pay (WTP) for the carbon labeling attribute, given that a majority of our respondents are urban residents in China who took part in the online survey. Secondly, the choice experiment, while striving to closely simulate real-choice scenarios, remains hypothetical and context-specific. Consequently, consumers might deviate from the hypothetical choices when faced with real commodities they cannot physically interact with. Thirdly, it is crucial to note that Huyou Pomelo is a specific type of citrus fruit, and the conclusions drawn in this paper may have limitations as consumer preferences vary across different products. To address these limitations, future research should encompass a broader spectrum of samples, employ diverse methods, and explore various research subjects to comprehensively gauge carbon label preferences and willingness to pay.

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Conflict of Interest

The authors declare no conflict of interest

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Appendix. Table A1 Goodness-of-fit measures of LCMs

Classes	BIC	AIC
2	11756.212	11666.026
3	11200.425	11045.106
4	11008.852	10788.398
5	10898.804	10613.216
6	10948.167	10597.445