frontiers | Frontiers in Environmental Science

TYPE Original Research
PUBLISHED 01 March 2023
DOI 10.3389/fenvs.2023.1109234

OPEN ACCESS

EDITED BY
Zahid Yousaf,
Government College of Management Sciences Mansehra, Pakistan

REVIEWED BY
Simona Andreea Apostu,
Bucharest Academy of Economic Studies, Romania
Shihong Zeng,
Beijing University of Technology, China

*CORRESPONDENCE
Yang Tan,
tanyang6969@163.com

SPECIALTY SECTION
This article was submitted to Environmental Economics and Management, a section of the journal Frontiers in Environmental Science

RECEIVED 27 November 2022
ACCEPTED 20 February 2023
PUBLISHED 01 March 2023

CITATION
Wang S, Tan Y, Fukuda H and Gao W (2023), Willingness of Chinese households to pay extra for hydrogen-fuelled buses: A survey based on willingness to pay.
Front. Environ. Sci. 11:1109234.
doi: 10.3389/fenvs.2023.1109234

Willingness of Chinese households to pay extra for hydrogen-fuelled buses: A survey based on willingness to pay

Shuai Wang[1], Yang Tan[2,3]*, Hiroatsu Fukuda[1] and Weijun Gao[1,4]

[1]Faculty of Environmental Engineering, The University of Kitakyushu, Kitakyushu, Japan, [2]Hangzhou City University, Hangzhou, China, [3]Zhejiang Engineering Research Center of Building's Digital Carbon Neutral Technology, Hangzhou, China, [4]Innovation Institute for Sustainable Maritime Architecture Research and Technology, Qingdao University of Technology, Qingdao, China

Hydrogen-fuelled buses play an important role in the construction of low-carbon cities as a means of green travel. Beijing, as a pilot city of hydrogen-fuelled buses in China, is very important in the promotion of hydrogen-fuelled buses in China. Unfortunately, the public acceptance of hydrogen-fuelledfuelled buses and their environmental positive externality value have not been studied. In this paper, we investigated the willingness of Beijing households to pay for the promotion of hydrogen-fuelled buses and its influencing factors by means of a web-based questionnaire. The spike model was also used to estimate the willingness to pay (WTP) for hydrogen buses. The results show that the WTP of Beijing households is CNY 3.19 per trip. The value of a positive environmental externality is approximately CNY 29.15 million per trip. Household income level, environmental knowledge, individual environmental ethics, and perceived behavioural control are the main influencing factors of WTP. Therefore, policymakers should strengthen publicity efforts to increase individuals' environmental awareness and environmental ethics and optimize the layout of hydrogen-fuelled bus schedules and riding experiences to improve individuals' perceptual and behaviour control. Finally, the positive environmental externality value of hydrogen buses should be valued, which will help increase investor interest.

KEYWORDS

willingness to pay, theory of planned behavior, hydrogen-fueled buses, spike model, contingent valuation method

1 Introduction

Due to the 2020 United Nations Climate Conference, carbon emission mitigation has attracted widespread attention all over the world. China, as the world's largest emitter of carbon, has made it an urgent priority to reduce its carbon emissions. China has made a commitment related to the Paris Agreement to achieve carbon neutrality by 2060. Hydrogen energy is an efficient and renewable clean energy source that plays an important role in the construction of low-carbon cities. With the promotion of the national "carbon neutral" and "carbon peaking" tasks, hydrogen energy, which is a green energy source, has received national attention and vigorous promotion, highlighting the importance of green energy for the construction of low-carbon cities (Zeng et al., 2022).

A hydrogen fuel vehicle (HFV) is an application of hydrogen energy. Thus, its energy conversion efficiency is high, and the reaction emission is water. Compared with conventional fuel vehicles, HFV emissions are pollution-free. Compared with pure electric vehicles, HFVs have obvious advantages, such as a short refuelling time and long driving range, which can effectively fill the inherent disadvantages of pure electric vehicles in medium- and long-distance transportation; these advantages represent important directions for the development of new energy vehicles in the future, as well as important parts of building low-carbon city systems.

In China, hydrogen-fuelled vehicles exist mainly in the form of hydrogen-fuelled buses. For the construction of a low-carbon city in 2022, the National Innovation-driven Development Strategy Outline and other important documents issued by the state clearly mention the vigorous development of hydrogen-fuelled vehicles. According to the "Beijing Municipal Hydrogen Fuel Cell Vehicle Industry Development Plan (2020–2025)" released by the Beijing Municipal Bureau of Economy and Information Technology at the service meeting, to accelerate the innovative development of Beijing's hydrogen fuel cell vehicle industry and support the construction of the national science and technology innovation centre, Beijing will focus on building a highland of innovation in the hydrogen fuel cell vehicle industry; furthermore, from 2016 to 2021, China's hydrogen fuel cell vehicle ownership increased annually, reaching 8,922 vehicles in 2021, accounting for 18% of the ownership of major countries in the world. According to the Medium and Long-term Plan for Hydrogen Energy Industry Development (2021–2035), the ownership of hydrogen fuel cell vehicles in China is expected to reach 50,000 vehicles in 2025 and be widely used in urban public transportation.

Although a series of national policies have been formulated to promote the development of hydrogen fuel cell vehicles, studies on the public acceptance of hydrogen-fuelled vehicles (especially hydrogen-fuelled buses) are still limited. This is not conducive for policymakers to develop appropriate promotion policies and is not good for increasing public awareness of the importance of environmental protection (Wang and Yue, 2022). Assessing the public's willingness to pay (WTP) is an important tool to measure public acceptance, which is of great social importance (Tan et al., 2022a). Assessing WTP helps to not only to understand public acceptance but also assess the environmental value of public environmental products. It also provides a reference value for policy formulation.

The construction of low-carbon cities with positive environmental externalities in terms of reducing urban carbon emissions and alleviating the use of fossil energy is a goal. In this respect, the use of hydrogen-fuelled buses has the effect of protecting the environment and has an environmental value. Therefore, such use can be considered a public environmental product, but its environmental value cannot be estimated by conventional methods. This is not conducive to the development and improvement of policies. It is also not conducive to the active participation of investors. Therefore, we use the contingent valuation method (CVM) to evaluate the WTP for hydrogen buses, to further understand the factors that affect the public WTP, and finally, to calculate the environmental value of hydrogen buses.

To date, many researchers have studied the public preference and WTP for hydrogen buses. O'Garra et al. (2007) conducted a comparative study of the public preference for hydrogen buses in Berlin, London, Luxembourg, and Perth. Respondents in all four cities were willing to pay extra for each bus, and the values were similar: V0.29 to V0.35 (V for Euro). Lin and Tan (2017) used a conditional value approach to study people's WTP for the adoption of new energy vehicles in four developed cities, namely, Beijing, Shanghai, Guangzhou, and Shenzhen. An interval regression model was used to analyse the factors influencing people's WTP and to estimate the exact amount of each payment. The results showed that approximately 80% of respondents in the four cities were willing to pay extra to support the adoption of new energy vehicles, with a specific amount of RMB 0.653/fare for all respondents. Yan and Zhao (2022) studied the factors influencing people's adoption trends and WTP for hydrogen fuel cell heavy-duty vehicles and analysed customers' WTP. The results showed that while customers were less willing to purchase hydrogen fuel cell heavy-duty trucks, the variables of purchase price, fuel cost, environmental awareness, and the number of heavy-duty trucks purchased had significant effects on participants' choices. People were willing to pay $116,099–131,579 for a hydrogen energy truck, with a WTP more than 50% higher than that for a heavy-duty diesel truck; furthermore, they were willing to pay no more than $1,548 per year for maintenance. Roche et al. (2010) reviewed and summarized the findings of public attitudes towards HFVs; the results showed that most people are not opposed to HFV. Other quantitative studies further prove that the public attitude is almost positive. From the abovementioned literature, we find that while the public acceptance and WTP for hydrogen-fuelled transportation has been widely studied worldwide, there is a lack of research on public attitudes and WTP for hydrogen-fuelled buses in Beijing, the capital city of China.

Beijing, as one of the first pilot cities in China to carry out the application of hydrogen-fuelled buses, is of reference in the promotion of hydrogen-fuelled buses in China. Therefore, this paper is the first study to investigate the WTP for hydrogen-fuelled buses among Beijing households and the factors influencing the WTP for hydrogen-fuelled buses and to assess the environmental value of hydrogen-fuelled buses.

The specific research flow is as follows. In the second part of the paper, a review of the literature is presented. In the third part, the methodology is presented. In the fourth part, the main results are analysed and discussed. In the fifth part, the conclusions are stated. In the sixth part, the policy implications are described.

2 Literature review

2.1 Research on WTP for new energy and hydrogen fuel

Most studies on the WTP for hydrogen fuel cell motor vehicles (HFCVs) are generally conducted from the following two aspects.

2.1.1 Demography and personal behaviour preference

Liu et al. (2022) analysed the factors influencing the HFCV consumption of respondents in Jiangsu Province, Zhejiang Province, and Shanghai, three major regions in the Yangtze River Delta. The results indicated that while gender, age, and income

differences may not be determinants of purchase, educational background is an important influencing factor. Consistent with social psychology research, personal environmental protection awareness and attitudes towards energy conservation are the key factors influencing HFCV consumption. Finally, the authors found that in the Yangtze River Delta, the confidence of consumers in hydrogen products in China is also an important influencing factor. Chen and Zhang (2021) constructed a structural equation model. The results indicated that the green purchasing behaviour of consumers completely mediates the positive correlation between social value perception and the purchasing intention of HFCVs. It was revealed through multigroup analysis that monthly income and gender could modulate the correlation between some study variables. Du et al. (2018) examined psychosocial factors based on an extended TPB model and explained the "awareness-behaviour" gap with low-carbon awareness as a regulatory variable. In addition, they obtained three main findings through correlation analysis and hierarchical multiple regression analysis. First, there is an "awareness-behaviour gap", namely, low-carbon awareness has a slight regulatory effect on purchasing behaviour through psychological factors. Second, subjective norms could exert a more significant impact on the WTP for new energy vehicles (NEVs) compared with other social and psychological factors. Third, the acceptability of policies also has a positive and significant impact on the acceptance of NEVs. Low-carbon awareness can be regarded as a regulatory variable that can enhance or weaken the WTP for NEVs. Rosales-Tristancho et al. (2021) investigated the WTP of Spanish drivers for HFCVs. They found that individuals with higher education levels, higher income levels, thorough insights into HFCVs, and a higher awareness of the negative consequences of fossil fuels in transportation with respect to environmental pollution and economic dependence are prone to accept HFCVs at an earlier stage. Huijts et al. (2013) explored the willingness of ordinary people to use hydrogen fuel facilities. The results indicated that personal moral perception has a significant influence on the use of hydrogen fuel facilities.

2.1.2 Product inherent attributes and social level

Nie et al. (2021) discussed whether industrial agglomeration could affect the WTP of customers for HFCVs. The empirical analysis results revealed that the industrial structure height of a city is positively correlated with the acceptance of customers for HFCVs. This outcome indicates that, in addition to economic and environmental factors, the agglomeration of industrial activities induced by industrial competition would increase the WTP of customers for HFCVs. Li et al. (2020) explored the public's WTP for the performance improvement of two different HFCVs. They confirmed that the public is willing to pay for the improvement in range, refuelling duration, fuel-saving amount, emission reduction and other aspects. Hardman et al. (2018) conducted a questionnaire survey on HFV owners in the United States. They found that HFVs can attract customers who cannot charge electric vehicles or install personal charging stations at home. They also found that the lack of charging or battery exchange stations is a major difficulty for the commercial success of HFVs. Yang et al. (2017) examined the public's willingness to support the policy of paying for the expansion of hydrogen stations in South Korea. They confirmed that the annual average WTP is KRW 2,258 (US $2.04), and the public is willing to bear a large part of the financial burden for the promotion of the policy.

The above analysis shows that gender, age, income, and educational background can influence WTP. As per a previous study conducted by our group, family member composition and health status could also have an impact on WTP (Tan et al., 2022b). The above six variables can be classified into the demographic category. Moreover, it can also be validated that relevant environmental knowledge and experience have an impact on WTP. Moral perception also influences the use of hydrogen fuel facilities. Therefore, the relationship between the above variables and WTP is discussed in this section.

2.2 Theory of planned behavior

The theory of planned behaviour (TPB) is the most basic theory in the field of behaviour. Based on the same assumptions as the theory of reasoned action (TRA), the TPB assumes that individuals usually engage in behaviours wisely, consider available information, and implicitly or explicitly consider the meaning of their behaviours. In this theory, behavioural intention is the strongest determinant of behaviours. According to the TPB, behaviour is controlled by behavioural intentions. The theory is composed of three core components, namely, attitude, subjective norms, and perceived behavioural control (PBC). Specifically, 1) attitude is a psychological emotion that can be conceived as an assessment of the consequences of a specific behaviour in rational choice; if a person has a positive attitude, he or she presents environmental behaviour; 2) subjective norms indicate that a person is subjected to social pressure from others, which may lead him or her to adhere to the beliefs of other people in some way; and 3) PBC refers to an individual's belief that he or she overcomes obstacles and performs a given behaviour. Hence, TPB is commonly used to explain various behavioural intentions. Of course, TPB has also been applied to research on HFCVs or NEVs. Wang et al. (2022) utilized the TPB to investigate the influence of Chinese consumers' attitudes, subjective norms, and PBC on their WTP for NEVs. The results indicated that the attitude towards the NEV policy is the main variable affecting WTP. Karuppiah and Ramayah (2022) explored the influence of TPB on the use of hybrid vehicles among the public in Malaysia. They found that high sensitivity to price weakened the positive correlation between PBC and WTP for hybrid vehicles. Huijts et al. (2013) adopted TPB to examine the Dutch public's intention to use hydrogenation facilities. The results showed that the TPB can influence the public's intention to use hydrogenation facilities.

As per the above analyses, it can be validated that TPB has been extensively used in the investigation of public attitudes towards new energy and the influencing factors related to its use. Therefore, TPB was also selected as a variable influencing WTP in this study.

2.3 Research on CVM

There are three main ways to induce the CVM, including payment-card, open-ended, and dichotomous-choice mode (Cummings et al.,1986). In terms of the payment-card mode, the interviewers can set multiple price options for the respondents to choose the most acceptable option. The payment-card mode has a

tendency to cause "rounding consumption", namely, that the WTP of respondents will be concentrated on the integer bidding point provided by interviewers (Zhou et al., 2009). In terms of the open-ended mode, respondents directly bid for the highest acceptable WTP. However, the disadvantage of the open-ended mode is a lack of a reference point on the "maximum payment", which induces a low response rate for the questionnaire (Meyerhoff and Liebe, 2006). In terms of the dichotomous-choice mode, interviewers would randomly question respondents within the determined bidding value range to observe whether they accept or reject the bid value. In contrast, the respondents under the dichotomous-choice mode only need to answer "Accept" or "Refuse" for a certain bidding value, without giving the specific value of their WTP, which contributes to preventing strategy bias in an incentive-compatible approach (Carson and Hanemann, 2005). The dichotomous-choice mode can be subdivided into single-bounded dichotomous choice (SBDC) and double-bounded dichotomous choice (DBDC). Due to the fact that DBDC is higher in the number of inquiries than SBDC, DBCD has higher accuracy (Cai et al., 2007). Therefore, DBDC is recommended by the National Oceanic and Atmospheric Administration (NOAA).

In CVM, zero response with the WTP of 0 often appears (Jorgensen et al., 2001), which would affect the estimation results. Many researchers directly eliminated zero response in previous studies, which may induce bias in the results (Almselati et al., 2015). The spike model is an effective method to deal with zero response (Kriström, 1997). In this model, it can be assumed that the distribution function of WTP cannot be zero at zero, which eliminates the deficiency that the conventional model cannot deal with the WTP samples with the value being 0. Benjamin and Mordechai. (1999) extended the spike model by adding covariates to estimate the total WTP, thus exploringthe factors influencing WTP. The effectiveness of the Spike model has been validated in some studies (Yoo and Kwak, 2002; Zhang et al., 2019; Tan et al., 2022a).

3 Data collection and methodology

3.1 Data collection

3.1.1 Site of data collection

In this study, a questionnaire survey was conducted in Beijing, the capital of China. Beijing has experienced traffic congestion and environmental pollution in recent years. Thus, it is an inevitable choice for the city to vigorously develop NEVs. There is a favourable development environment for the hydrogen energy automobile industry in Beijing owing to the many industrial support policies, famous universities, and powerful research institutions in this city. In addition, during the 2022 winter Olympics, hydrogen-fuelled buses were vigorously promoted as vehicles for green travel. Based on these facts, Beijing was selected as the survey site.

3.1.2 Questionnaire survey method

1) Data Sources

Questionnaire surveys have become a mainstream method for investigating the public's attitude towards environmental products (Tan et al., 2022b). This survey method can be divided into face-to-face interviews, telephone interviews, and online questionnaire surveys. Telephone interviews are not a commonly used method due to their higher costs and longer duration. Face-to-face interviews are considered an efficient way to collect questionnaires. This method can help respondents understand the details of questionnaires and provide real-time answers to the questions of respondents. However, it is difficult to adopt face-to-face interviews on a large scale due to the current epidemic prevention restrictions in China. With the increased number of internet terminal devices in China, the number of mobile internet users in China has reached 1.007 billion, thereby providing a great level of convenience for the implementation of online questionnaire surveys. This method can ensure the completion of this online questionnaire survey. In view of the cost and epidemic prevention situation in China, an online questionnaire survey was selected as the data collection method in the current study.

The Schaeffer equation is used in sample selection to determine sample size. The effectiveness of this method has been proven and is widely used in sample size confirmation (Scheaffer et al., 1996; Wang et al., 2018; Tan et al., 2022a; Tan et al., 2023).

$$U = T/(K-1)e^2 + 1$$

where U is the sample size, T is the total sample size, and e is the acceptable error. Given that Beijing has a population of 21.8 million, the ideal valid sample size should be no less than 400. Considering influencing factors such as invalid questionnaires in the questionnaire survey, the effective sample size should not be less than 500. The effective sample size of 564 in this study meets the requirements of the Scheaffer equation. Questionnaire Star allows the IP addresses of interviewees to be set within the range. We stipulated that the IP addresses be limited to the Beijing area and that all samples meet the set range. Therefore, it can be considered that our study conforms to the geographical setting and has applicability.

These questionnaires were collected with the assistance of the Wenjuanxing platform (https://www.wjx.cn/), which is the largest online questionnaire survey platform in China; there are more than 190 million users and more than 15 billion questionnaires on the platform. Since this study was conducted in Beijing, tutors, students, and friends in this city were invited to randomly distribute these online questionnaires to Beijing residents to obtain valid samples. This questionnaire survey was conducted on respondents aged 18–65 years in Beijing. A total of 800 questionnaires were distributed, and 610 responses were obtained, including 565 valid questionnaires and 45 invalid questionnaires. The invalid questionnaires included protest responses and questionnaires with failures, for instance, the respondent contended that there was a lack of authenticity for the project or that the government should pay for this project.

2) Payment Instruments

The abrupt inclusion of WTP in an online questionnaire survey frequently leaves respondents perplexed, and discussing the proposed payment method is helpful in disclosing the genuine payment purpose (Zhang et al., 2019). Taxes, entry tickets, ticket payments, and other means are the principal payment instruments. According to Carson

et al. (2001), adopting mandatory and widespread payment methods can significantly lessen payers' excessive commitment. Thus, relevant questions about income tax and consumption tax were clarified in a presurvey.

3.1.3 Data collection process

Before the formal questionnaire survey, a presurvey was conducted based on a sample size of 50 respondents. The presurvey was performed to determine the bidding value, bidding scope, and payment instruments.

Bus tickets were chosen as the payment method based on the findings of the presurvey because these tickets are both required and well known to the respondents. Additionally, in this procedure, three sets of bidding values overall were established, and six bidding points, including 0.5, 1, 2, 3, and 4, were chosen. The selection of 0.5 and 4 was avoided in the first round of inquiry to prevent missing bidding points in the second round of inquiry. These three groups' bid values were sorted from small to large as CNY (0.5/1/2) (1/2/3), and (2/3/4).

The questionnaire was composed of four parts. The first part was involved in the demographic data of respondents, including gender, age, educational background, work, household income level, family member composition, and health status. The second part included five questions designed for obtaining the respondents' understanding of hydrogen energy or associated vehicles, the experience of hydrogen fuel cell buses, policy concerns, and environmental awareness. These questions are presented as follows. Do you know about hydrogen energy or related vehicles? Do you know about policies related to hydrogen energy? Have you ever taken hydrogen fuel cell buses? Do you know about policies related to hydrogen energy or HFVs? Do you think that using hydrogen fuel cell buses can help alleviate urban carbon emissions? The third part was related to TPB, including three questions. From the perspective of attitudes, in order to build a low-carbon city (improve the environment, purify the air, *etc.*), would you actively choose the hydrogen fuel cell bus as a means of travel? From the perspective of subjective norms, do your family members or friends support you to choose the hydrogen fuel cell bus as a means of travel? From the perspective of PBC, do you have enough resources to pay extra for hydrogen fuel cell buses? Although the government is actively promoting hydrogen fuel cell buses as a vehicle for green travel, there are certain financial burdens. Considering the positive environmental externalities of hydrogen fuel cell buses (zero emissions, improved air quality and other positive effects) and the financial pressure faced by the government, would you or your family members pay extra fees for the promotion of hydrogen fuel cell buses (the bus ticket is CNY 2) every time you take the bus under the premise that your status is fully considered? This is the core issue about the WTP for hydrogen fuel cell buses.

3.2 Methodology

3.2.1 The conventional DBDC-CVM model

In the conventional DBDC format, respondents would be asked whether they are willing to pay or accept the bidding value of a specific amount C_i ($i = 1, \ldots, n$). The first answer of "Yes" or "No" would be regarded as a reference basis for the second inquiry to adjust the bidding amount. As for WTP, when the answer of the respondents is "Yes" for the first time, another higher bidding amount C_i^H would be asked for the second time, otherwise they would be provided with another lower bidding amount C_i^L, i.e., $C_i^L < C_i < C_i^H$; The T denotes the response after a given amount C_i, willing to pay then $T = Y$ and refusal to pay then $T = N$.Therefore, there are four possible outcomes: unwilling-unwilling, unwilling-willing, willing-unwilling, and willing-willing. The binary-indicator variables would be A_i^{NN}, A_i^{NY}, A_i^{YN}, and A_i^{YY}, respectively. $G_c(C; X)$ represents the cumulative distribution function (CDF) of WTP, C represents the bidding value, Y represents an unknown parameter that needs to be valued, and the logarithmic likelihood function can be expressed as follows.

$$\begin{aligned}\ln L = \sum_{i=1}^{N}\{&\mathbf{A}_i^{YY}\ln\left[1 - G_c\left(\left(C_i^H; Y\right)\right)\right] + \mathbf{A}_i^{YN}\ln\left[G_c\left(C_i^H; Y\right)\right.\\ &-G_c\left(Ci; Y\right)] + \mathbf{A}_i^{NY}\ln\left[G_c\left(C_i; Y\right) - G_c\left(C_i^L; Y\right)\right]\\ &+\mathbf{A}_i^{NN}\ln G_c\left(C_i^L; Y\right)\}\end{aligned}$$

Formulating 1 —G_c (.) as logistic CDF and combining this with Y = (α, β) yields

$$Gc\left(C_i;\ Y\right) = \left[1 + \exp\left(\alpha - \beta A\right)\right]^{-1}$$

3.2.3 Spike model

Chinese residents may not know enough about the policies related to hydrogen fuel cell buses due to their small number. Besides, the overall income level of the public is not high in China, a developing country. Most Chinese residents have a weak environmental awareness, and they are unfamiliar with CVM scenarios. Hence, there would be respondents who choose to refuse to pay (zero response) in the questionnaire survey. As a result, the spike model proposed by Kriström (1997) and Benjamin and Mordechai. (1999) combined with SBDC was employed to deal with zero response.

The spike model is established based on the modification of DBDC-CVM. In case the respondents are required to answer subsequent questions when the answer is No-No ((A_i^{NN})), they would be asked if they are willing to join the market again. If the answer is "Yes" ((A_i^{NNY})), they would be estimate by the spike model. The spike model allows the probability of 0 WTP to be a certain positive decimal. If the answer is "No" ((A_i^{NNN})), the reason why they are unwilling to join the market would be asked to judge whether the respondent belongs to a protest group. If it is judged as a protest response, the sample would be eliminated.

The formula can be expressed as follows

$$\begin{aligned}\ln L = \sum_{i=1}^{N}\{&A_i^{YY}\ln\left[1 - G_c\left(C_i^H; Y\right)\right] + A_i^{YN}\ln\left[G_c\left(C_i^H; Y\right)\right.\\ &-G_c\left(C_i; Y\right)] + A_i^{NY}\ln\left[G_c\left(C_i; Y\right) - G_c\left(C_i^L; Y\right)\right]\\ &+A_i^{NNY}\left[\ln G_c\left(C_i^L; Y\right) - G_c\left(0; Y\right)\right] + A_i^{NNN}\left[G_c\left(0; Y\right)\right]\}\end{aligned}$$

In which

$$G_c\left(C_i;\ Y\right) = \begin{cases} 0 & if\ A < 0 \\ \left[1 + \exp\left(\alpha\right)\right]^{-1} & if\ A = 0 \\ \left[1 + \exp\left(\alpha - \beta A\right)\right]^{-1} & if\ A > 0 \end{cases}$$

The spike is defined by $[1 + \exp(\alpha)]^{-1}$. The average mean WTP can be computed as $\bar{C} = (1/b)\ln[1 + \exp(\alpha)]$

TABLE 1 Response distribution.

Bid amount	YY	YN	NY	NNY	NNN	Sum
(0.5/1/2) CNY	108 (57%)	50 (27%)	17 (9%)	4 (2%)	9 (5%)	188 (100%)
(1/2/3) CNY	98 (52%)	45 (24%)	16 (9%)	10 (5%)	19 (10%)	188 (100%)
(2/3/4) CNY	89 (47%)	40 (21%)	14 (7%)	12 (6%)	33 (19%)	188 (100%)
sum	295 (52%)	135 (24%)	47 (8%)	26 (5%)	61 (11%)	564 (100%)

4 Results

4.1 Data statistics

In this study, Beijing was selected as the research site. Because children under 18 years old and elderly individuals over 65 years old may have incomplete cognition, a questionnaire survey was administered to respondents aged 18–65 years in this study. The online questionnaire survey format was adopted as the means by which to distribute 800 online questionnaires in total. Ultimately, 610 responses were obtained, and 107 respondents withheld payment. Thus, the protest response judgement was performed on these 107 respondents, according to the protest response judgement standard in some relevant extant articles (Meyerhoff and Liebe, 2010; Meyerhoff et al., 2012). During the judgement, a total of five questions were established, among which A and B represent the true zero response, and C, D, and E represent the protest response. After the judgement, there were 564 valid questionnaires and 46 protest response questionnaires.

A: Economic pressures.

B: I am not interested in low-carbon urban construction.

C: There is a lack of authenticity for the project.

D: The government project has nothing to do with me.

E: The use of hydrogen fuel cell buses has no contribution to the environment.

Among them, there were 51 respondents in option A, 14 respondents in option B, eight respondents in option C, 24 respondents in option D, and 10 respondents in option E. Therefore, there were 564 valid questionnaires and 46 protest response questionnaires. Due to the random distribution of protesters in the sample, these surveys can be directly eliminated. The remaining 564 questionnaires were analysed, and the sample size was in line with that determined by the Scheaffer formula (Scheaffer et al., 2011).

The distributed responses of respondents in each bidding group are listed in Table 1. With the increase in the bidding value in the bidding group, the number of respondents who were willing to pay gradually decreased, while the number of respondents who refused to pay gradually increased. Approximately 57% of respondents in the lowest bidding group agreed to pay the lowest bidding value (CNY 2), and 47% of respondents in the highest bidding group agreed to pay the highest bidding value (CNY 4). In addition, 89% of respondents had a WTP larger than 0, and approximately 11% of these respondents were judged as zero response samples.

The mean and standard deviation (SD) of each covariate in these statistical samples are listed in Table 2. The official data on gender, age, working status, educational background, and income can be obtained from the Beijing Municipal Bureau of Statistics. By comparison, it can be observed that there was a significant difference in age and income between the obtained data and the official data, while there was no significant difference in gender, working status, and educational background between the obtained data and the official data. The deviation from the official data may have been caused by younger mobile phone users and fewer elderly mobile phone users. This difference may also be due to the number of samples, which induces some limitations in regard to the spot check. Except for age, there was no significant difference in other variables. Therefore, it can be maintained that the sample in this study was suitable for estimating the WTP of the whole population.

Through population comparison, there was a relatively high proportion of respondents aged 26–45 years. Furthermore, respondents with jobs and households containing elderly individuals or children accounted for the majority. Most respondents were in good health. Approximately 60% of the respondents had a household income exceeding the average level in Beijing. Approximately 65% of the respondents had a basic concept of hydrogen energy. More than 80% of the respondents maintained that hydrogen-fuelled buses contribute to alleviating urban carbon emissions, and they were willing to choose these buses as green travel vehicles. In the answer to psychological covariate questions related to TPB, more than 60% of the respondents provided positive responses.

4.2 Estimation results

The maximum likelihood estimate (MLE) function was utilized to estimate the parameters, with the estimation results listed in Table 3. These variables were classified into four variable groups. Then, these variables in the four groups were estimated (four estimation Models 1-4 were established). Subsequently, the influence of these variables on WTP was discussed. The four variable groups included the demographic variable group (Model 1), the demographic and environmental knowledge variable group (Model 2), the demographic, environmental knowledge, and moral perception variable group (Model 3), and the demographic, environmental knowledge, moral perception, and planned behaviour variable group (Model 4). In Model 1, there was a positive correlation between income level and WTP at 1% of the statistical level. In Model 2, there was a positive correlation between income level and WTP at 1% of the statistical level. In addition, there was a correlation between environmental knowledge and WTP at the 5% statistical level. In Model 3, there was a positive correlation between income level and WTP at 1% of the statistical level. In addition, there was a correlation between environmental knowledge and WTP at the 5% statistical level. In addition, there was a positive correlation between personal moral level and environmental moral cognition at the 1% statistical level. In Model 4, there was a positive

TABLE 2 Sample statistics and definition of variables.

Variable	Option	Numbers	Proportion/%	Mean	Dev	Census
Demographic attributes						
Gender	Male = 1	260	46.2	0.46	0.50	0.50
	Female = 0	302	53.8			
Age	18 ≤ Age <25 = 0	152	26.9	0.85	0.60	1.21
	26 ≤ Age ≤45 = 1	344	61.6			
	45 < Age ≤65 = 2	65	11.5			
Education	University degree or above = 1 others = 0	310	55.3	0.55	0.49	0.41
		252	44.7			
Job	Have job = 1	404	72.0	0.72	0.45	0.51
	No = 0	158	28.0			
Raising children or elder	Old or young = 1	458	81.6	0.82	0.38	—
	No = 0	104	18.4	—	—	—
Physical condition	Health = 1 others = 0	422	75.2	0.75	0.43	—
		140	24.8			
Household Income	More than 35549 CNY = 1 others = 0	337	60.1	0.60	0.49	0.54
		225	39.9			
Relevant knowledge and experience						
Related environment knowledge	Have the knowledge = 1 others = 0	367	65.5	0.65	0.48	
		195	34.5			
Related experience	Have = 1 others = 0	264	46.9	0.47	0.50	
		298	53.1			
Related policy knowledge	Yes = 1	293	52.3	0.52	0.50	
	others = 0	269	47.7	—	—	
Moral implications						
Cognition of environmental morality	Yes = 1	480	85.6	0.86	0.35	—
	No = 0	82	14.4	—	—	—
Moral	Yes = 1	473	84.3	0.84	0.36	—
	No = 0	89	15.7	—	—	—
Theory of planned behavior						
Attitude	Yes = 1	441	78.6	0.79	0.41	—
	No = 0	121	21.4			
Subjective norm	Yes = 1	474	84.5	0.85	0.36	—
	No = 0	88	15.5			
Perceived behavioral control	Yes = 1	355	63.3	0.63	0.48	—
	No = 0	207	36.7			

correlation between income level and WTP at 1% of the statistical level. In addition, there was a positive correlation between personal moral level and environmental moral cognition at the 1% statistical level. Among the TPB-related variables, PBC was significant at 1% of the statistical level. Subjective norms were significant at 10% of the statistical level. There was no significant correlation between attitudes and WTP. The abovementioned four models show that there was a significant positive correlation between income level and WTP in the four

TABLE 3 Covariance estimation results.

Variable	Model 1		Model 2		Model 3		Model 4	
	Coef	*p* values	Coef	*p* values	Coef	*p* values	Coef	*p* values
Constant	1.196	0.009	0.887	0.003	0.458	0.000	−0.019	0.000
Demographic attributes								
Gender	0.122	0.460	0.014	0.933	0.043	0.801	0.014	0.932
age	0.244	0.084*	0.152	0.291	0.153	0.291	0.161	0.271
education	0.319	0.056*	0.237	0.159	0.242	0.152	0.255	0.134
income	0.784	0.000***	0.661	0.000***	0.661	0.000***	0.615	0.000***
Job	0.185	0.321	0.122	0.514	0.092	0.625	0.076	0.690
family	0.185	0.382	0.168	0.430	0.136	0.528	0.131	0.548
health	0.239	0.195	0.257	0.166	0.285	0.125	0.219	0.244
Family members (social psychology)								
Environment knowledge	—	—	0.468	0.032**	0.461	0.036**	0.457	0.037**
Experience	—	—	0.298	0.089*	0.308	0.086*	0.342	0.090*
Related policy knowledge	—	—	0.383	0.072*	0.351	0.092*	0.361	0.086*
Moral								
environment moral	—	—	—	—	0.619	0.004***	0.504	0.023***
moral	—	—	—	—	0.681	0.001***	0.657	0.002***
Theory of planned behavior								
Attitude	—	—	—	—	—	—	0.511	0.957
Subjective norm	—	—	—	—	—	—	0.393	0.084*
Perceived behavioral control	—	—	—	—	—	—	0.633	0.000***
Bid	0.731	0.000***	0.769	0.000***	0.777	0.000***	0.790	0.000***
spike	0.106	0.000***	0.105	0.000***	0.105	0.000***	0.107	0.000***
MTP	3.163	0.000***	3.149	0.000***	3.154	0.000***	3.191	0.000***
95% confidence interval	2.956–3.182	—	2.923–3.138	—	2.929–3.143	—	2.928–3.387 CNY	—
99% confidence interval	2.947–3.183	—	2.915–3.140	—	2.920–3.144	—	2.861–3.469 CNY	—

Notes: The unit of MTP, is CHY, *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

models. This outcome indicates that the higher the income of the interviewed households is, the more willing they are to pay to support the use of hydrogen-fuelled buses as green travel vehicles. Knowledge and experience related to HEVs, moral perception, subjective norms, and PBC in TPB also exert a significant positive impact on WTP.

Among the estimation results of the four models, the value of the peak model closest to the zero response of our samples can be observed in Model 4, and there was no significant difference (the zero response of the sample was 10.8%, while the peak value was 10.7%). Therefore, the estimation results of Model 4 were selected as those of WTP, and the average WTP was CNY 3.19. The 99% confidence interval (CI) was CNY [2.861, 3.469].

According to data from the Seventh National Population Census in China, the number of households in Beijing is 9.138 million. If the WTP can be extended to all households in Beijing, then the WTP of all households would be approximately CNY 29.15 million (namely, the environmental positive externality value). Thus, it can be considered that all the households in Beijing would be willing to provide a total of CNY 29.15 million as financial support to the government for the promotion of hydrogen-fuelled buses every time they take these buses.

4.3 Descriptive analysis

As hydrogen-fuelled buses are still a relatively new concept, the public may know less about them. Therefore, the respondents with knowledge related to hydrogen energy were further asked to understand the approach to acquiring associated knowledge among them. This line of inquiry may

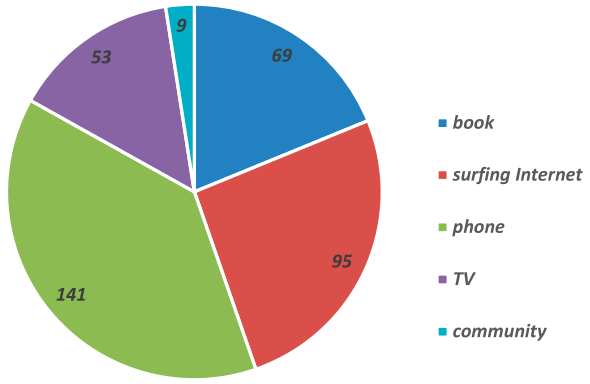

FIGURE 1
Access to information.

contribute to providing a reference for the publicity of hydrogen-fuelled buses. In this study, 367 respondents who had knowledge related to hydrogen energy were further asked where they obtained this information. Among them, 69 respondents had obtained relevant knowledge through books, 95 respondents had obtained relevant knowledge through the internet, 53 respondents had obtained relevant knowledge through TV, 141 respondents had obtained relevant knowledge through mobile phones, and nine respondents had obtained relevant knowledge through community publicity, as shown in Figure 1.

5 Discussion

Some interesting results can be found through this study, including the factors influencing households' WTP for hydrogen-fuelled buses in Beijing and their WTP. The formulation of relevant policies and the promotion of public participation have enlightening significance for the promotion of hydrogen-fuelled buses. Although some researchers have performed extensive studies on hydrogen energy vehicles, there is still a lack of in-depth exploration into the public's WTP for hydrogen-fuelled buses in Beijing and the relevant influencing factors. China has the largest output of carbon emissions in the world. The findings of this study based on Beijing are expected to promote the promotion of hydrogen-fuelled buses in China, which may provide a reference for green travel in China.

5.1 WTP and relevant influencing factors

Among demographic variables, there is a significant positive correlation between income level and WTP, which is consistent with the conclusion of Rosales-Tristancho et al. (2021) that high-income respondents tend to be more active in environmental protection.

However, some researchers have also contended that there is a positive correlation between income and educational background (Tan et al., 2022b). In this study, educational background is correlated with WTP at 10% of the statistical level in Model one but is not significant in other models. This is different from the conclusions drawn by relevant researchers (Tan et al., 2022a). This difference may be explained by the fact that some high-income respondents with a higher educational level would not choose buses as vehicles, and they often drive private cars. Therefore, these respondents were classified as protest responders and excluded from the sample in this study. Environmental knowledge, relevant experience, and policy-related knowledge all have a certain positive correlation with WTP, which is similar to some research results (Yang et al., 2017; Rosales-Tristancho et al., 2021; Tan et al., 2022b). Those respondents who have environmental knowledge, understand relevant policies, and have riding experience are often interested in hydrogen-fuelled buses or take these buses as vehicles for green travel. For those respondents without relevant knowledge, increasing their experience opportunities or strengthening the publicity of relevant knowledge or policies may have a dramatic effect on the acceptance of hydrogen-fuelled buses. The moral factor has always been considered an important factor influencing WTP, and its effectiveness has been widely proven in studies on WTP (Huijts et al., 2013; Zhang et al., 2021). It can be found through this study that environmental moral factors and moral factors have a significant correlation with WTP. This is consistent with the research results of Huijts et al. (2013); i.e., the personal perception of moral factors often urges individuals to actively participate in related activities that are beneficial to the public, including paying for hydrogen energy and paying for heat island mitigation. Therefore, it is necessary to increase moral education for policymakers and make individuals actively participate in environmental protection.

The theory of planned behaviour (TPB) has become the most important theory in exploring individual behaviours in recent decades (Tan et al., 2022a; Zhang et al., 2019). This theory is mainly composed of three variables, namely, attitudes, subjective norms, and perceived behavioural control (PBC). There was no significant correlation found between attitudes and WTP, which is similar to the conclusions of some researchers (Zhang et al., 2019; Zhang et al., 2021). Subjective norms were found to be significant at the 10% level, and PBC was significant at the 1% level. As a dominant variable affecting WTP in TPB, PBC could also exert an impact on WTP. This is different from the opinion of Ajzen et al. (1991), who argued that attitudes, subjective norms, and PBC can all exert an impact on individual behaviours. This difference may be explained by the fact that WTP is not a payment behaviour but rather occurs before the behaviour. It may also be explained that although attitude is the driving factor of behaviours, it could be affected by subjective norms and perceived behaviours. For example, an individual could have a positive attitude, but either people who have a close relationship with him or her (subjective norms) could prevent this individual from engaging in a certain behaviour or his or her resources (PBC) could not support him or her to engage in a certain behaviour; therefore, the driving force (attitude) may be inhibited. PBC is the variable that has the most significant influence on WTP according to the TPB. When respondents think that they have enough resources, they support the promotion of hydrogen-fuelled buses. In this study, both income level and PBC exerted a significant impact on WTP. Zhang et al. (2021) also proposed that income level is a part of PBC. Due to the influence of COVID-19 in China, a certain economic recession has occurred. Therefore, an approach that improves the income and PBC of residents is a consideration that should be addressed by policymakers.

We found a strong positive correlation between WTP and knowledge and experience related to hydrogen-fuelled buses; thus, it is essential to increase the dissemination of relevant knowledge to increase WTP for them. Cell phones are currently a widely used

communication tool. More than 38% of respondents said that they obtain information is through their cell phone. Surfing online and watching TV are also important ways to obtain information. This is similar to the findings of Tan et al., 2022a and Zhang et al. (2019); thus, these three information dissemination channels should be used as the primary means by which to increase knowledge dissemination and increase free hydrogen bus trial rides, which may help to increase the public's WTP and promote the construction of low-carbon cities.

The estimation result of WTP is CNY 3.19 per ride, which is nearly five times higher than the research result of Lin and Tan found in 2016 (the average WTP for NEVs in Beijing, Shanghai, Guangzhou, and Shenzhen was CNY 0.653). It can be assumed that there are three main reasons for this difference. First, as zero-emission vehicles, hydrogen-fuelled buses are more significant than new energy (electric and hybrid) buses in terms of positive environmental externalities. Second, Beijing was the first pilot city to use hydrogen-fuelled buses in China during the 2022 winter Olympics; thus, residents in this city have more thorough insight into these buses and more direct experience related to these buses. Finally, with the convening of the 2020 UN Climate Change Conference, the signing of the Paris Agreement, and the establishment of carbon neutrality and peak carbon dioxide emissions in China, the Chinese public has paid more attention to the construction of low-carbon cities. This is also consistent with the influence of environmental knowledge and moral factors on WTP in this study.

6 Conclusion and policy recommendations

This study examines the WTP and the factors influencing the WTP of Beijing households to support the promotion of hydrogen-fuelled buses. To better estimate the results, a peak model was used to deal with zero responses based on the two-boundary dichotomous conditional value method. The spike value was very close to the proportion of actual zero responses in the sample. This indicates that the model fits well. The WTP per household in Beijing is CNY 3.19 per ride. All the households in Beijing are willing to provide a total of CNY 29.15 million in financial support to the government for every ride on a hydrogen-fuelled bus to promote hydrogen-fuelled buses. Income related to hydrogen buses, policy perceptions, hydrogen vehicle riding experience, personal ethics, environmental ethics, subjective norms, and perceived behavioural control positively influence WTP. Among them, income level, environmental ethics, personal ethics, and perceptual behaviour control are statistically significant at the 1 percent level and have a strong positive relationship with WTP.

Based on the above findings, we propose four policy recommendations for promoting the promotion of hydrogen-fuelled buses.

First, the pricing of hydrogen bus tickets should be appropriately increased, and extra revenue should be used to promote the positive environmental externalities of hydrogen buses.

Second, the internet (*via* cell phones and computers) is the primary way that the public receives information about hydrogen-fuelled buses; thus, online promotion should be the primary way to increase respondents' environmental knowledge and ethical awareness.

Third, the hydrogen bus ride experience should be optimized by increasing the number of hydrogen buses, allowing hydrogen buses to use Beijing's dedicated bus lanes and ensuring a smooth commute to and from work during peak hours. This would help increase individual perceptual and behavioural control (ride comfort, time savings) and thus promote the popularity of hydrogen buses.

Fourth, the public's WTP needs to be brought to the attention of policymakers. Furthermore, it should be mentioned when bidding for hydrogen energy buses.

Because this part of the value may be ignored by the relevant investors, emphasizing the public's WTP will help increase investors' interest in investing and thus promote the development of hydrogen vehicles.

It must be acknowledged that there are still some limitations in our study; in addition, due to the differences in income levels and uneven development across China, there may be a range of deviations in the level of willingness to pay across the country. Therefore, it is very important for future studies to minimize the bias caused by income differences and regional development imbalances.

Data availability statement

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

Ethics statement

The studies involving human participants were reviewed and approved by Japan Society for the Promotion of Science. The patients/participants provided their written informed consent to participate in this study. The animal study was reviewed and approved by Japan Society For The Promotion of Science.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Funding

This research is partially funded by the University of Kitakyushu Fukuda lab, Japan; the National Natural Science Foundation of China (72140001); the Beijing Natural Science Foundation (9222002).

Conflict of interest

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

Publisher's note

References

Ajzen, I. (1991). The theory of planned behavior. *Organ. Behav. Hum. Decis. Process.* 50 (2), 179–211. doi:10.1016/0749-5978(91)90020-t

Benjamin, R., Mordechai, S., et al. (1999). Incorporating zero values in the economic valuation of environmental program benefits. *J. Environ. Wash. D C)* 10, 87–101. doi:10.1002/(sici)1099-095x(199901/02)10:1<87::aid-env339>3.0.co;2-q

Cai, C.-G., Chen, G., Qiao, X.-C., and Zheng, X.-Y. (2007). Comparison of single bound and double bound dichotomous contingent valuation technique—A case of estimate health economic loss by air pollution of beijing. *China Environ. Sci.*, 39–43.

Carson, R. T., Flores, N. E., and Meade, N. F. (2001). Contingent valuation: Controversies and evidence[J]. *Environ. Resour. Econ.* 19 (2), 173–210. doi:10.1023/a:1011128332243

Carson, R. T., and Hanemann, W. M. (2005). Contingent valuation[J]. *Handb. Environ. Econ.* 2, 821–936.

Chen, M., and Zhang, W. H. (2021). Purchase intention for hydrogen automobile among Chinese citizens: The influence of environmental concern and perceived social value. *Int. J. Hydrogen Energy* 46 (34), 18000–18010. doi:10.1016/j.ijhydene.2020.11.099

Cummings, R. G., Brookshire, D. S., Bishop, R. C., et al. (1986). *Valuing environmental goods: An assessment of the contingent valuation method[M].* Rowman and Littlefield Pub Incorporated.

Du, H., Liu, D., Sovacool, B. K., Wang, Y., Ma, S., and Li, R. Y. M. (2018). Who buys new energy vehicles in China? Assessing social-psychological predictors of purchasing awareness, intention, and policy[J]. *Transp. Res. Part F Traffic Psychol. Behav.* 58, 56–69. doi:10.1016/j.trf.2018.05.008

Hardman, S., Jenn, A., Tal, G., Axsen, J., Beard, G., Daina, N., et al. (2018). A review of consumer preferences of and interactions with electric vehicle charging infrastructure. *Transp. Res. Part D Transp. Environ.* 62, 508–523. doi:10.1016/j.trd.2018.04.002

Huijts, N. M. A., De Groot, J. I. M., Molin, E. J. E., and van Wee, B. (2013). Intention to act towards a local hydrogen refueling facility: Moral considerations versus self-interest. *Transp. Res. Part A Policy Pract.* 48, 63–74. doi:10.1016/j.tra.2012.10.006

Jorgensen, B. S., Wilson, M. A., and Heberlein, T. A. (2001). Fairness in the contingent valuation of environmental public goods: Attitude toward paying for environmental improvements at two levels of scope. *Ecol. Econ.* 36 (1), 133–148. doi:10.1016/s0921-8009(00)00210-x

Karuppiah, V., and Ramayah, T. (2022). Modeling hybrid cars adoption using an extended version of the theory of planned behavior. *Transp. Lett.*, 1–13. doi:10.1080/19427867.2022.2091677

Kriström, B. (1997). Spike models in contingent valuation. *Am. J. Agric. Econ.* 79 (3), 1013–1023. doi:10.2307/1244440

Li, W., Long, R., Chen, H., Chen, F., Zheng, X., He, Z., et al. (2020). Willingness to pay for hydrogen fuel cell electric vehicles in China: A choice experiment analysis. *Int. J. Hydrogen Energy* 45 (59), 34346–34353. doi:10.1016/j.ijhydene.2020.01.046

Lin, B., and Tan, R. (2017). Are people willing to pay more for new energy bus fares? *J. Energy* 130, 365–372. doi:10.1016/j.energy.2017.04.153

Liu, J., Chen, T., and Hu, B. (2022). Consumer acceptance under hydrogen energy promotion policy: Evidence from Yangtze River Delta. *Int. J. Hydrogen Energy*. doi:10.1016/j.ijhydene.2022.07.081

Meyerhoff, J., and Liebe, U. (2010). Determinants of protest responses in environmental valuation: A meta-study. *Ecol. Econ.* 70 (2), 366–374. doi:10.1016/j.ecolecon.2010.09.008

Meyerhoff, J., and Liebe, U. (2006). Protest beliefs in contingent valuation: Explaining their motivation. *Ecol. Econ.* 57 (4), 583–594. doi:10.1016/j.ecolecon.2005.04.021

Nie, X., Wei, X., Xia, Q., and Zhou, M. (2021). Customers' purchase intention for hydrogen vehicle and industrial agglomeration: Evidence from Jiangsu Province, China. *Int. J. Hydrogen Energy* 46 (34), 18011–18019. doi:10.1016/j.ijhydene.2020.10.055

O'Garra, T., Mourato, S., Garrity, L., Schmidt, P., Beerenwinkel, A., Altmann, M., et al. (2007). Is the public willing to pay for hydrogen buses? A comparative study of preferences in four cities[J]. *Energy Policy* 35 (7), 3630–3642. doi:10.1016/j.enpol.2006.12.031

Roche, M. Y., Mourato, S., Fischedick, M., Pietzner, K., and Viebahn, P. (2010). Public attitudes towards and demand for hydrogen and fuel cell vehicles: A review of the evidence and methodological implications. *Energy policy* 38 (10), 5301–5310. doi:10.1016/j.enpol.2009.03.029

Rosales-Tristancho, A., Carazo, A. F., and Brey, R. (2021). A study of the willingness of Spanish drivers to pay a premium for ZEVs. *Energy Policy* 149, 112091. doi:10.1016/j.enpol.2020.112091

Scheaffer, R. L., Mendenhall, W., III, Ott, R. L., et al. (2011). *Elementary survey sampling[M].* Cengage Learning.

Scheaffer, R. L., Mendenhall, W., and Ott, L. (1996). *Elementary survey sampling*. fifth ed. Boston: PWS-Kent.

Tan, Y., Fukuda, H., Li, Z., Wang, S., Gao, W., and Liu, Z. (2022a). Does the public support the construction of battery swapping station for battery electric vehicles?-Data from Hangzhou, China[J]. *Energy Policy* 163, 112858. doi:10.1016/j.enpol.2022.112858

Tan, Y., Fukuda, H., Zhang, L., et al. (2022b). An investigation into residents' willingness to pay for vertical greening in China[J]. *Urban Ecosyst.*, 1–12.

Tan, Y., Ying, X., Gao, W., Wang, S., and Liu, Z. (2023). Applying an extended theory of planned behavior to predict willingness to pay for green and low-carbon energy transition. *J. Clean. Prod.* 387, 135893. doi:10.1016/j.jclepro.2023.135893

Venkatachalam, L. (2004). The contingent valuation method: A review. *Environ. impact Assess. Rev.* 24 (1), 89–124. doi:10.1016/s0195-9255(03)00138-0

Wang, C., Yao, X., Sinha, P. N., Su, H., and Lee, Y. K. (2022). Why do government policy and environmental awareness matter in predicting NEVs purchase intention? Moderating role of education. *level[J]. Cities* 131, 103904. doi:10.1016/j.cities.2022.103904

Wang, X., and Yue, X. (2022). A study on the mechanism of the influence of short science video features on people's environmental willingness in social media—based on the SOR model[J]. *Front. Environ. Sci.*, 1611.

WangLiSun, Y. X. M., and Yu, H. (2018). Managing urban ecological land as properties: Conceptual model, public perceptions, and willingness to pay. *Resour. Conservation Recycl.* 133, 21–29. doi:10.1016/j.resconrec.2018.01.038

Yan, J., and Zhao, J. (2022). Willingness to pay for heavy-duty hydrogen fuel cell trucks and factors affecting the purchase choices in China. *Int. J. Hydrogen Energy* 47, 24619–24634. doi:10.1016/j.ijhydene.2022.03.252

Yang, H. J., Cho, Y., and Yoo, S. H. (2017). Public willingness to pay for hydrogen stations expansion policy in Korea: Results of a contingent valuation survey. *Int. J. Hydrogen Energy* 42 (16), 10739–10746. doi:10.1016/j.ijhydene.2017.02.079

Yoo, S-H., and Kwak, S-J. (2002). Using a spike model to deal with zero response data from double bounded dichotomous choice contingent valuation surveys. *Appl. Econ. Lett.* 9 (14), 929–932. doi:10.1080/13504850210139378

Zeng, S., Tanveer, A., Fu, X., Gu, Y., and Irfan, M. (2022). Modeling the influence of critical factors on the adoption of green energy technologies. *Renew. Sustain. Energy Rev.* 168, 112817. doi:10.1016/j.rser.2022.112817

Zhou, X. H., Jian-Zhang, M. A., Zhang, W., et al. (2009). Evaluating the economic value of endangered species conservation with contingent method and its reliability analysis —|A case study on the willingness to pay of the citizens in harbin on amur[J]. *J. Nat.Resour.* 24 (2), 276–285.