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Consumers' Willingness to Pay for the Solar Photovoltaic System in the Post-Subsidy Era: A Comparative Analysis under an Urban-Rural Divide

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Abstract: Concerns about the environment and renewable energy are growing. Improving the perception of renewable energy in urban and rural households is required to promote green development and to learn about consumer preferences for renewable energy based on the gradual reduction in financial subsidies for photovoltaic (PV) power generation. This paper aims to estimate the willingness of consumers to pay for a Household PV system and explores the factors that affect consumers' product selection, which is conducive to optimizing Household PV products and policies and is important for achieving the carbon peaking and carbon neutrality goals. Using a discrete choice model, this paper surveyed 765 urban and rural residents without installing Household PV systems in Tianjin, China. Subsequently, the respondents' attribute preferences and willingness to pay (WTP) for a Household PV system were analyzed using a logit regression analysis model. The influence of respondents' socio-economic characteristics on WTP was analyzed. The empirical results showed that (1) price significantly impacts consumers' PV adoption behaviors and consumers tend to choose cheaper PV products; (2) consumers are more willing to pay for the after-sales service (3959 USD/level) and traceable information (2176 USD/level), indicating their preference for these two attributes when considering options; (3) socio-economic variables, including gender and the number of minor children (i.e., children under the age of 18) at home, significantly impact consumers' PV adoption behaviors. Males and consumers without minor children at home will pay more attention when selecting the products. Our research findings will provide valuable insights into policy making and the wide-ranging use of Household PV systems.

Keywords: Household PV; environmental awareness; willingness to pay; choice experiment

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1. Introduction

Transforming the energy structure and combating climate change are important issues for global sustainable development. The 2030 Agenda for Sustainable Development, published by the United Nations, proposes to ensure access to affordable, reliable, sustainable and modern energy for all and to take urgent action to combat climate change and its impacts [1]. So, it is important to promote the widespread use of renewable energy, such as photovoltaic (PV) power generation in this context. PV power generation technology has already been used in both developed and developing countries. With technological progress and market expansion, the cost of PV power generation continues to decrease [2], which has resulted in the government's expiration adjustment of the subsidy policy, including developed countries (e.g., USA, UK) and developing countries (e.g., China).

At the 75th session of the General Assembly of the United Nations, China announced its goal of achieving peak carbon and carbon neutrality and has a long-term commitment to this goal. For years, China's approach to promoting the domestic adoption of PV products has mainly focused on subsidies as a purchasing stimulus. With technological advances, the cost of PV power in China has dropped significantly. According to the data of the 21st Century Renewable Energy Policy Network (REN21), the price of China's PV power generation per kilowatt-hour (kWh) of electricity has reduced by 72% from 2010 to 2017.

Meanwhile, vast subsidies have significantly pressured the Chinese government's finances. By the end of 2017, the cumulative PV subsidy had reached USD 6.3 billion. This is about 40% of the total subsidy for China's renewable energy power generation [3]. Due to financial constraints, China's central government has gradually formulated a plan to decrease these subsidies. In 2018, the subsidy for PV power generation decreased from 0.058 USD/kWh (tax included) to 0.051 USD/kWh. In 2021, the subsidy for newly installed Household PV systems had fallen to 0.004 USD/kWh [4].

The subsidy has been widely used as a short-term policy to promote purchasing and installing renewable energy technologies. The discontinuation of subsidies has a negative effect on the diffusion of renewable energy technologies by weakening consumers' purchase tendencies. Due to the high installation fees associated with Household PV systems, Chinese consumers rely heavily on government subsidy programs to adopt these renewable energy systems. Household PV products will become less affordable once subsidies are discontinued. Therefore, consumers will pay more attention to the attributes of Household PV products, including the nature of such products and the quality of services businesses provide. To maintain a healthy Household PV market in China, policy-making processes in this area and adjustments to pricing are on the agenda. Thus, the purpose of the study is to find out which product attributes will be the key factors influencing consumers' choice of Household PV products in the post-subsidy era, as the cost of adopting Household PV increases due to subsidy reduction and to measure how much they are willing to pay once subsidies end. The findings will provide valuable insights for policy making and market adjustments to facilitate the continued promotion of PV products.

Renewable energy is an effective tool for increasing energy utilization efficiency. As a result, many scholars have investigated renewable energy sources and technologies such as PV power [5–7], natural gas [8,9], biomass [10,11], electric vehicles [12,13], CO_2 capture, storage [14,15] and transportation [16], among which solar PV has won widespread attention due to its promising development prospects. Based on relevant national policies, many scholars have adopted different methods to study consumer preferences and willingness to pay (WTP) in both developed and developing countries. For example, Lee et al. [17] used the contingent valuation method (CVM) to evaluate consumers' WTP for renewable energy in South Korea. Ryan [18] explored which policy incentives are more effective at increasing the electricity generated from solar PV via the OLS estimator in America. Entele et al. [19] used a two-variable probability model to analyze the preferences of 220 rural Ethiopian households for grid and solar power generation. Alhammami [20] added relevant policies for research by exploring the economic impact of the subsidies on solar energy in the UAE. Wang et al. [21] demonstrated the contribution of urbanization and changes in consumption patterns to carbon emissions by using a factor-reversible structural decomposition method featuring input–output analysis. Other scholars discussed the impact of the urban–rural income gap on rural carbon emissions. For example, Wang et al. [22] studied the impact of a lowered urban–rural income gap on carbon emission reduction and pollution control using the OLS (Ordinary Least Square) method based on panel data from 30 provinces in China from 2006 to 2017. Some scholars have studied the impact of low-carbon products and carbon labels on consumers' WTP. For example, a study conducted in China examined the factors affecting consumers' choice behavior for low-carbon products, and the results showed that the delivery speed of low-carbon products, consumers' patience and degree of satisfaction had significant effects on consumers' WTP [23]. Xu et al. [24] studied the impact of socio-economic characteristics on consumers' WTP for carbon labeled products. Evidence from Korea showed that, as concerns about climate change are growing, there is a significant preference for mandatory carbon labels [25]. Many scholars adopted the discrete choice experiment (DCE) approach in various countries to study consumers' WTP.

For example, a discrete choice experiment was conducted to estimate individuals' WTP for different typologies of domestic PV plants in Italy [26]. A DCE implemented in Aguascalientes, Mexico, showed that respondents had a positive WTP for renewable energy and green jobs [27]. Despite several WTP studies for PV adoption, they did not reveal the changes in consumer preferences for PV product attributes at a time of subsidy reductions, thus leaving a gap regarding new factors affecting consumers' choice of the Household PV system.

Based on this, the marginal contributions of our study to the existing literature about consumers' preferences for Household PV products are presented as follows: (1) Our principal contribution to the existing literature was applying a DCE to measure Chinese consumers' WTP for each product-specific attribute of Household PV products regarding subsidy termination. By estimating consumers' WTP for each attribute or characteristic of Household PV, we could derive the relative strength of product-specific factors in determining household adoption behaviors of PV products in the event of a gradual reduction in subsidies. Additionally, we incorporated demographic and socio-economic variables into the multinomial logit model to study the heterogeneous preferences of consumers. Our study could contribute to increasing the applicability of the CEM approach and permit the evaluation of renewable energy policy instruments. (2) Previous studies have mainly focused on policy research [28,29] and market analysis. Limited quantitative studies have focused on Household PV generation from the Chinese consumers' WTP perspective, as this analysis relies heavily on microdata. To fill this knowledge gap, our study aimed to conduct a questionnaire survey to study Chinese consumers' WTP for Household PV products. (3) Previous studies have neglected to investigate heterogeneous preferences among different populations when analyzing consumers' choice behaviors for Household PV products. Our study was designed to fill this gap by adding heterogeneous preferences to the analysis process. Specifically, our study focused on consumer psychology and conscious behaviors by analyzing the sociodemographic characteristics of households without installing Household PV in Tianjin, China. (4) The findings derived from the consumers' WTP perspective could be used as the basis for policy formulation. Enterprises and governments could adjust sales strategies and relevant policies according to consumer psychology and behaviors, thus increasing Household PV product sales and fulfilling the continuous development goal of China's distributed PV industry. The objective of the study is to determine the attribute preferences and willingness to pay of urban and rural Chinese consumers for Household PV generation equipment in the post-subsidy era. In particular, it explored what drives them to purchase Household PV power generation equipment. A questionnaire survey of 765 households randomly selected in Tianjin, China, was initiated to address these objectives. A discrete choice modeling approach was adopted to examine consumers' Household PV power generation equipment choices. The consumers' WTP for each attribute of Household PV equipment was quantified. Heterogeneous preferences among different populations were also investigated. The findings will provide valuable insights into policy making and market adjustments to facilitate the continued promotion of PV products.

The overall structure of the study takes the form of seven sections. Section 2 briefly summarizes the relevant studies regarding consumers' preferences and WTP for renewable energy technologies. Section 3 covers the econometric model used in this study. Section 4 introduces the survey design and issues concerning data collection. Sections 5 and 6 present the empirical results and discussions. The final section concludes this study and presents the policy implications.

2. Literature Review

Willingness to pay refers to the degree to which consumers are willing to pay for a product, service or facility with a specific characteristic or function (like money, property, etc.). Extensive research has adopted the concept of WTP to estimate consumers' valuation of services and goods concerned with renewable energy resources, such as bioethanol [30], new energy vehicles [31], green electricity [32], nuclear energy [33] and domestic energy-saving appliances [34]. In response to global warming, the United Nations has made a strong call for carbon reduction [35]. As more countries are promoting the development and deployment of renewable energy technologies, much of the current literature on WTP is paying particular attention to consumers' WTP for adopting household renewable energy technologies. An investigation in Nepal used the contingent valuation method to assess respondents' WTP for domestic biogas plants [36]. Moreover, a choice experiment approach was employed to investigate consumers' WTP for a novel carbon label in the US [37]. Finally, a "parameterization + calibration" approach was used to address the stated intention and omitted-variable bias and estimate customers' WTP for PV [38]. These studies highlight the urgent need to evaluate consumers' preferences and WTP for renewable energy technologies.

Analysis of the driving factors of the consumer's WTP may help policymakers formulate objective development plans for renewable energy technologies. Previous studies on the factors influencing consumers' WTP for renewable energy technologies have suggested that the driving factors can be broadly classified into socio-economic, product-specific and sociodemographic characteristics. The socio-economic factors include policy participation, the level of urbanization and social norms. Consumers with a higher participation level in renewable energy planning, satisfaction with implementing renewable energy policies and recognition of the high cost of renewable energy are more willing to use renewable energy [39]. When consumers are eager to pay for green energy, social norms usually exist in all frameworks [40]. A product-specific factor refers to the features of the renewable energy technologies that may be offered to households facing such a choice, including price, quality and transparency of information. In an investigation of European consumer demand for electrical appliances, quality was the critical factor influencing consumers' purchasing behaviors [41]. Sociodemographic factors such as gender, education, age, family income and the number of family members significantly affect consumers' willingness to pay for renewable energy technologies. A research study in southwestern Nigeria examined the factors influencing the citizens' willingness to pay (WTP) for renewable electricity, and found that age, income, marital status and education level are significant factors [42]. A study in Japan found that women and the aging population tend to have a higher WTP for locally produced renewable electricity [43]. Other factors, such as environmental attitudes, also contribute to consumers' WTP for renewable energy technologies. A behavioral experiment using a sample group from Amazon Mechanical Turk (MTurk) found that consumers with high protected values had higher green energy adoption intentions and were more agreeable to paying a premium [44].

From a methodology perspective, previous studies on WTP were mainly carried out using the stated preference method. The contingent valuation method (CVM) and the choice experiment method (CEM) are well established and commonly applied techniques that can be employed to estimate consumers' WTP for environmental goods or services. The CVM is the most widely accepted method for evaluating the value of resources, environmental products and services and assesses a consumer's WTP by constructing a hypothetical market or scenario. Contingent valuation generally defines a good with a fixed set of attributes and requires respondents to answer "yes" or "no" to whether they would pay or accept a certain amount of money for the product in question, where the costs proposed to vary across respondents [45]. The CVM has been used in a study measuring farmers' WTP for renewable energy in Nigeria. The CVM was used to prompt responses and estimate the WTP for a pico-photovoltaic (pico-PV) system and improved cook stove [46].

The choice experiment method describes the products, services or policies being evaluated with multiple attributes at different levels, which makes it easier to estimate people's WTP for particular attributes. In a discrete choice experiment (DCE), respondents are provided with choice sets containing different alternatives (e.g., values of the good's attributes). Participants are requested to select the alternative they prefer from those presented. In contrast to the CVM, the CEM can assess the value of individual attributes rather than a single, well-defined product. Consequently, the CEM is more suitable for calculating consumers' WTP for different product attributes than for a specific category of products. Considering Household PV products, choice experiments enable researchers to understand how respondents value various sets of services that a product could provide. Analysis results can provide policymakers with valuable insights about particular attributes or services. A discrete choice study was conducted in Eindhoven, the Netherlands, to assess homebuyers' preferences for installed PV systems due to a lack of accurate market data. The responses of 227 homebuyers indicated that PV systems were more attractive to homebuyers in urban or central neighborhoods, and only 4% of respondents appreciated the aesthetic appearance of PV plants [47]. Another relevant study adopted a flexible choice-based conjoint approach to investigate the key drivers influencing Swiss homeowners' preferences for domestic rooftop PV plants. The results show that the country of origin and the color of the PV modules were the most important driving factors [48].

While extensive research has been carried out on consumers' preferences and WTP for renewable energy technologies, there are still three main limitations in the existing literature: (1) Research on the impact of PV product attributes on consumers' PV adoption is insufficient. For example, several scholars have explored the impact of price on residential PV adoption [49], but much less is known about consumers' WTP. Although power [50,51] and lightening protection devices [52,53] have been confirmed to have a significant impact on the performance of PV products, no scholars have examined whether these attributes have an impact at the level of consumer choice. Other attributes that may influence consumers' preferences and WTP have not been studied in the existing literature, such as production origin, traceability information and after-sales service. In fact, in the Chinese market environment, consumers are quite concerned about the production process and the materials used for products, especially for electricity-using products, including the total amount of information, the coverage links and the accuracy of the information. The impact of after-sales service is particularly significant in the context of subsidy reductions and the rising costs of using PV products, as consumers want to avoid the potential costs of possible product damage. Considering these, additional research on product attributes is necessary. (2) From the methodology perspective, there is considerable room for improvement in the applicability of the CEM in research to assess consumers' willingness to pay for detailed attributes of consumer renewable energy technologies. The DCE measures consumer purchasing behavior based on an experimental design by simulating the competitive market environment for the product/service, in order to obtain information on how consumers choose between different levels of product/service attributes and prices [54], which helps to improve existing research. (3) Another major limitation of the existing literature is that previous research results on WTP for renewable energy technologies are challenging to apply directly to the current situation. Many countries have made remarkable strides in the early stage of promoting renewable energy technologies by offering purchase and installation subsidies for consumers. Solar PV technology is spreading rapidly in developed countries and making progress in developing countries [55,56].With the rapid development of new energy technologies, the cost of PV products has dropped appreciably. The government has embarked on adjusting the subsidy policy. The discontinuance of purchase and installation subsidies poses a challenging situation for developing and deploying renewable energy technologies. It is therefore important to examine consumers' preferences for PV products and WTP in the post-subsidy era.

In this study, we explored the social preferences regarding the detailed attributes of installing a Household PV system in China. We also aimed to quantitatively predict public acceptance of detailed attributes of Household PV products through the simulation of virtual Household PV products. The results will help provide valuable insights into policy making and the wide-ranging use of Household PV systems.

3. Econometric Model

3.1. Discrete Choice Experiment

The DCE is a multivariate nonlinear statistical method. It is an effective and practical research technique widely used for investigating consumers' preferences for products in the energy sector [57].

Based on experiments, the DCE method measures the consumer's choice behavior by simulating the combination of different attributes. In a survey questionnaire, respondents are required to complete several choice tasks. In the choice task, the respondent must repeatedly select his/her preferred alternative from a given choice set. Each alternative is formulated by attributes that form the product under investigation. After data collection, the respondents' choices could be regressed on the attributes to estimate the effect of attribute levels on choice.

The underlying microeconomic model of DCE is the random utility model, which allows the calculation of the WTP values for each attribute separately. According to the theory of utility maximization outlined in the random utility model, the rational consumer tends to select the alternative where they can maximize the utility derived from the attributes of a product when faced with a choice. As demonstrated in Equation (1), for choice set J, alternative i has a more excellent utility to the individual than all the other choices; therefore, the individual will select alternative i:

$$U_i > U_j \ (i, j \in J, \ i \neq j) \tag{1}$$

Due to the potential errors in the measurement process, the utility function is usually assumed to be linear in the modeling parameters. The utility function consists of an observable deterministic component V_i and a random component ε_1 where β is a vector of parameters.

$$U_i = V_i + \varepsilon_i = \beta_1 X_{i1} + \beta_2 X_{i2} + \cdots + \beta_K X_{iK} + \varepsilon_i = \beta'^{X_i} + \varepsilon_i \tag{2}$$

In the equation, WTP for attribute a_k is defined as the trade-off between a change in the attribute and a price change where β_{price} is the coefficient of the price paid for the attribute.

$$WTP_k = -\frac{\beta_k}{\beta_{price}} \tag{3}$$

Our study primarily aimed to estimate consumers' WTP for each attribute of a Household PV product. Therefore, a questionnaire survey using a discrete choice model (DCM) was conducted. We established a multiple-choice model to formulate random combinations of the various attributes of the Household PV product. These randomly constructed combinations were then set as different alternatives for the respondents to select in the given choice tasks. We adopted the utility function to calculate consumers' WTP for each attribute of a Household PV product.

3.2. Multinomial Logit Model

According to the multinomial logit model, the probability that the respondent will choose alternative i from choice set $J \ (I, j \in J, i \neq j)$ is

$$P_i = exp(\beta_k X_{ki}) / \sum_{j=1}^{J} exp(\beta_k X_{kj}) \tag{4}$$

To study respondents' heterogeneous preferences for Household PV products, it is essential to incorporate demographic and socio-economic variables into the logit model. The MNL model (Multinomial Logit Model) is frequently used to interpret and calibrate mode-choice data [58].

To achieve the research objectives, this study focused on consumers in the post-subsidy era. Firstly, consumers' attitudes towards environmental issues were examined. Then, the reasons for not installing Household PV were studied through descriptive statistics. Subsequently, based on questionnaire results, consumers' preferences for attributes and WTP for PV products were investigated by a discrete choice model and logit regression analysis. At last, the impact of consumers' socio-economic characteristics was explored. The research framework is as Figure 1:

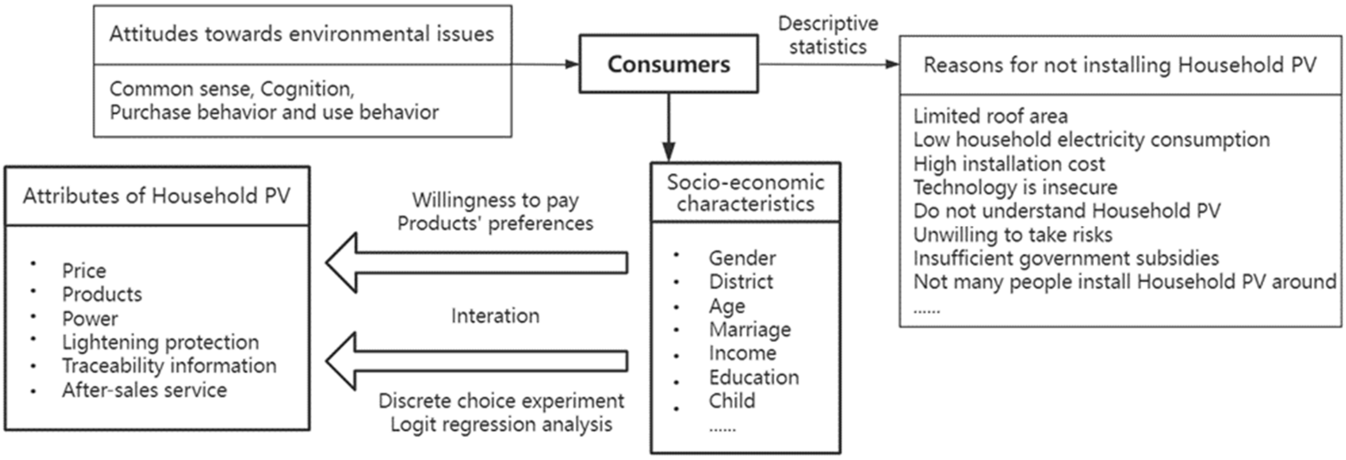

Figure 1. Research framework.

4. Survey Design

4.1. Design of the Discrete Choice Experiment

4.1.1. Attribute Setting

In the DCE method, the consumer's selection process of Household PV products can be regarded as the consumer's choice of a combination of Household PV product attributes. Therefore, consumers' choice behaviors under different scenarios can be viewed as a trade-off process. By utilizing appropriate attributes, it is possible to avoid interference caused by unreasonable aspects of the experimental design, ensuring that the questionnaire is accurate and facilitating the analysis of the psychological processes that influence consumer decision making.

After fully considering the nature of Household PV and the quality of services provided by businesses, our study selected six attributes and established each attribute's value. Table 1 lists the selected attributes of our DCE approach and their corresponding levels. The attributes included:

1. Price [59];
2. Whether it is a product of the Beijing-Tianjin-Hebei region [60,61];
3. Power [62];
4. Whether additional lightening protection devices need to be purchased (whether the lightening protection level of the product itself is not satisfactory) [63];
5. Traceable information (whether the production process and materials it used can be known) [64];
6. After-sales service.

Each attribute is briefly described below.

Price. The price of a product is one of the most critical factors for consumers when making a purchase decision. There are two components to the cost of using Household PV. One is the purchase and installation price, which is generally between USD 2760 and 13,801, and the other is the poll purchase price (PPP). The latter refers to the price for electricity purchased by the power grid that connects to the primary grid. Currently, there are three resource areas in China: Type I, Type II and Type III. The PPP of Type I, Type II and Type III resource areas are adjusted to 0.076 USD/kWh, 0.09 USD/kWh and 0.1 USD/kWh (including tax), respectively. Despite Tianjin being a Type II resource area, the PPPs for different participants were consistent. In this case, we only considered the cost of the purchase and installation.

Whether it is a product of the Beijing-Tianjin-Hebei region. For consumers, production locations are also essential when making a purchase decision. Due to the different production locations, the convenience of transportation and installation varies. Therefore, this attribute was selected.

Power. The power of existing products differs, although generally, three levels exist consisting of 5 kW, 10 kW and 20 kW.

Whether additional lightening protection devices need to be purchased. As most Household PV devices are installed outdoors, they are incredibly vulnerable to lightning strikes, especially during thunderstorms. Thus, installing both external and internal lightening protection devices is extremely important. Some existing Household PV products are purchased with an AC lightening protection distribution cabinet. However, consumers must pay extra fees when purchasing products with additional lightening protection devices, such as lightning distribution cabinets. Due to its importance, we selected this attribute.

Traceable information. An essential aspect of traceable information is the likelihood of determining the production process and the materials used. In determining the quality level of traceable information, several factors must be considered, including the total amount of information, the coverage links and the accuracy of the information. Accordingly, from an integrity perspective, traceable information can be classified into three levels: no traceable information, low quality (i.e., incomplete traceable information) and high quality (i.e., complete traceable information).

After-sales service. Whether the after-sales service is comprehensive and reliable is another factor consumers consider when choosing Household PV products. According to the integrity of the after-sales service, this attribute is divided into the following three levels: no after-sales service, low after-sales service (one-year warranty, etc.) and high after-sales service (lifetime warranty and one-year replacement).

Table 1. Attributes and levels used in the choice experiments.

Attribute	Attribute Level		
Price	2759	5517	11,035
Products [a]	Yes	No	
Power	5 kw	10 kw	20 kw
Lightening protection [b]	Yes	No	
Traceability Information [c]	No traceability information	Low quality [d]	High quality [e]
After-sales service	No aftersales service	Low after-sales service [f]	High after-sales service [g]

[a] products from the Beijing-Tianjin-Hebei region; [b] purchase additional lightening protection devices (whether the lightening protection level of the product itself is not satisfactory); [c] traceability information (whether production process and materials used can be known); [d] incomplete traceability information; [e] complete traceability information; [f] warranty within one year, etc.; [g] lifetime warranty, one-year replacement. Same below.

4.1.2. Orthogonal Experiment

The key to designing DCE is efficiently constructing selection sets. However, the random combination of options will produce too many selection sets, creating a considerable workload for the questionnaire survey and subsequent analysis. It may also lead to lower reliability. The orthogonal experiment is a method to study multiple factors and levels and can effectively avoid this problem. It dramatically reduces the number of selection sets, simplifies the experimental process and increases the feasibility.

In our experiment, six attributes of Household PV were selected. Among them, four attributes each had three levels, while the remaining two had two levels. Random combinations could generate 324 selection sets ($3 \times 3 \times 3 \times 3 \times 2 \times 2$). Since too many choices will distort consumer results, 16 selection sets were generated by an orthogonal experiment, allowing the main effects to be estimated. The orthogonal test results are shown in Table 2.

Table 2. Orthogonal test results.

Serial Number	Price	Products	Power	Lightening Protection	Traceability Information	After-Sales Service
1	5517	YES	20KW	YES	1 [h]	1 [k]
2	2759	YES	10 KW	YES	3 [j]	3 [m]
3	2759	YES	10 KW	NO	2 [i]	1
4	2759	YES	5 KW	NO	1	2 [l]
5	5517	NO	5 KW	NO	2	3
6	2759	NO	20 KW	YES	2	1
7	11,035	NO	10 KW	NO	1	1
8	5517	NO	10 KW	YES	1	2
9	11,035	YES	5 KW	YES	2	2
10	11,035	YES	20 KW	NO	1	3
11	2759	NO	5 KW	YES	1	3
12	2759	NO	5 KW	NO	1	1
13	11,035	NO	5 KW	YES	3	1
14	5517	YES	5 KW	NO	3	1
15	2759	NO	20 KW	NO	3	2
16	2759	YES	5 KW	YES	1	1

[h] no traceability information; [i] low quality (traceability information is incomplete); [j] high quality (traceability information is complete); [k] no after-sales service; [l] low after-sales service (within one year warranty, etc.); [m] high after-sales service (with a lifetime warranty and one-year replacement).

Next, four kinds of choice cards were formulated with four selection sets. The choice cards were designed to simulate the decision-making process when the respondent in Tianjin has to select a product. Each respondent was presented with four choice cards consisting of four selection sets. In addition, the "Do not choose" option was designed to ensure the accuracy of the data. The designed choice cards were placed in the fifth part of the questionnaire to study consumers' choice preferences for Household PV.

4.2. Questionnaire Development

The formal questionnaire was composed of three parts: the questionnaire description (Section 1), questions regarding the topic (Sections 2–5) and questions about the socio-economic characteristics of the respondents (Section 6). The first section of the questionnaire introduced the objective of our survey. The importance of truthful answers was clearly emphasized to reduce hypothetical market bias [65]. A privacy protection statement was also outlined.

The second section of the questionnaire comprised 17 basic questions regarding the basic situation of a Household PV installation, such as whether to install a Household PV product. We further inquired about the reasons for those not installing such products. For those using a Household PV, we inquired about the installation time and reasons, access to information and attitudes to relevant policies.

Considering that a Household PV system is a new type of sustainable energy technology, consumers' attitudes toward environmental issues will also impact the adoption and installation of the product. Therefore, the third section of the questionnaire, referring to relevant research scales in this field, was conducted from alternative perspectives, including rationality, cognition and purchase and usage behavior. We produced a total of 25 items in the three modules. The items reflected respondents' concerns about the current environmental situation.

The fourth section of the questionnaire, consisting of 42 items in five modules, was designed to investigate the respondents' viewpoints on the adoption and installation of a Household PV system compared to a traditional power system. In addition, this part examined the respondents' attitudes toward China's subsidy policy for Household PV systems.

The fifth section of the survey formed the main body of the questionnaire. This section was composed of four selection sets based on the level of each attribute in Table 1. The choice cards determined by the orthogonal experiment were presented to study consumers' choice preferences for Household PV products. Table 3 shows the four kinds of choice cards.

Table 3. Choice cards.

Feature	Product 1	Product 2	Product 3	Product 4	
Price	5517	2759	2759	11,035	Do not choose
Products	Yes	Yes	No	No	
Power	20 kw	5 kw	20 kw	5 kw	
Lightening protection	Yes	No	Yes	Yes	
Traceability information	No	No	Low	High	
After-sales service	No	Low	No	High	
Tick under your favorite product	☐	☐	☐	☐	☐
Feature	**Product 1**	**Product 2**	**Product 3**	**Product 4**	
Price	2759	11,035	2759	5517	Do not choose
Products	Yes	No	No	Yes	
Power	10 kw	10 kw	5 kw	5 kw	
Lightening protection	No	No	Yes	n	
Traceability information	Low	No	No	High	
After-sales service	No	No	High	No	
Tick under your favorite product	☐	☐	☐	☐	☐
Feature	**Product 1**	**Product 2**	**Product 3**	**Product 4**	
Price	2759	11,035	11,035	2759	Do not choose
Products	Yes	Yes	Yes	No	
Power	10 kw	5 kw	20 kw	5 kw	
Lightening protection	No	Yes	No	No	
Traceability information	High	Low	No	No	
After-sales service	High	Low	High	No	
Tick under your favorite product	☐	☐	☐	☐	☐
Feature	**Product 1**	**Product 2**	**Product 3**	**Product 4**	
Price	5517	5517	2759	2759	Do not choose
Products	No	No	No	Yes	
Power	5 kw	10 kw	20 kw	5 kw	
Lightening protection	No	Yes	No	Yes	
Traceability information	Low	No	High	No	
After-sales service	High	Low	Low	No	
Tick under your favorite product	☐	☐	☐	☐	☐

The last section of the questionnaire consisted of 15 questions regarding the socio-economic characteristics of the respondents, including gender, age, education and family structure.

The final questionnaire consisted of the combined six sections as mentioned above.

4.3. Reliability and Validity

We believe that under the current environmental conditions, consumers' perceptions of the environment will affect their final purchases of Household PV products. Therefore, we first analyzed the third part of the questionnaire about the respondents' rationality, cognition and purchase and usage behavior. Because this paper is an exploratory study, we first had to analyze the reliability of the test scale using Cronbach's α reliability test. The value of Cronbach's α was 0.793 and 0.815 for the standardized items. Both values were greater than 0.7, indicating that the scale's reliability was good. Then, the scale validity was tested using the Kaiser-Meyer-Olkin test and Bartlett's Test of Sphericity to verify whether the questionnaire results were accurate, and whether they could effectively explain the respondents' perceptions and attitudes toward the environment. The results showed that the Kaiser-Meyer-Olkin value was 0.882, and the significance of Bartlett's test was 0.000, indicating that the correlation coefficient was not an identity matrix. Thus, the scale was suitable for factor analysis. In the total variance analysis, the first five factors explained 47.29% of the variance, which contained most of the information. According to Table 4, considering the factor load value, most drawbacks were closely related to component 1. Combined with the descriptive statistical results, it is evident that consumers' awareness of environmental protection is relatively good, and most of the respondents are eco-friendly.

Table 4. Composition matrix.

Var.	Item	Factor Load Value	
		1	2
Environmental value	EV2 [n]	0.622	
	EV3	0.548	
	EV4	0.576	
	EV5		0.595
	EV6	0.504	
	EV7		0.573
	EV10	0.517	
Environmental attitude	EA1 [o]	0.504	
	EA2	0.607	
	EA3	0.560	
	EA6		0.584
	EA7	0.605	
Environmental knowledge	HEC1 [p]	0.557	
	HEC2	0.528	

[n] EV means the acronym of environmental value; [o] EA means the acronym of environmental attitude; [p] HEC means the acronym of human environmental customs. The extraction method is the main component analysis method. The factor rotation method is maximum variance method. Items with a factor load value less than 0.5 have been deleted.

4.4. Sample and Data Collections

Our survey was conducted on a sample group of consumers in Tianjin, China, using both the offline and online questionnaire methods. The respondents were selected from Ji County and Tianjin City via a stratified sampling method to reduce the errors caused by regional factors. Before the formal investigation, a pretest survey of a random sample consisting of 200 respondents was conducted. This test aimed to seek results and feedback for the amendment of the survey construction. To encourage the respondents to complete the questionnaire earnestly, a cash reward of USD 0.7 was sent to each online questionnaire respondent. In addition, rice and oil worth USD 4.1 were sent to each offline questionnaire respondent. The formal survey was conducted from November to December 2019. In November, 73 villagers in Ji County completed the offline questionnaire. In December, 922 respondents from Tianjin completed the online questionnaire.

5. Results

5.1. Descriptive Statistics and Complaint Responses

At the end of the formal survey, 995 questionnaires were received that passed the quality control test. As mentioned earlier, each questionnaire had four choice cards, indicating that each respondent had to make four choices, creating 16 observations. For personal questions, there were a total of 16 options. Among all the respondents, a total of 765 respondents have not installed a Household PV system. Thus, a total of 12,240 (765 $\times$ 16) observations were formed. Among these, 3792 "do not choose" observations were eliminated, leaving 8448 observations. The background information of the respondents who have not installed a Household PV system is shown in Table 5. The essential social characteristics of the participants, such as gender, region, age and head of a household, were relatively evenly distributed. The reasons for not installing a Household PV system are presented in Table 6. A total of 528 respondents (69.02%) did not install a Household PV product because they "Do not understand Household PV", while 378 respondents (49.41%) reasoned that "Not many people install Household PV around here". Therefore, the attitudes and practices of the people and those around them drastically impact the respondents' subjective consciousness. In addition, "high installation cost", "limited roof area" and "low household electricity consumption" also affected respondents' choices.

Table 5. Summary of sample demography (N = 765).

Background		Frequency	Percentage (%)
Gender	Male	427	55.8
	Female	338	44.2
District	Urban	342	44.7
	Rural	423	55.3
Age	18~25	280	36.6
	26~35	275	35.9
	36~45	119	15.6
	46~60	85	11.1
	>60	6	0.8
Marriage	Yes	384	50.2
	No	367	48.0
	Other	14	1.8
Owner	Yes	345	45.1
	No	420	54.9
Income	≤13,794	316	41.3
	13,795~41,381	387	34.7
	41,382~68,968	47	6.1
	≥689,684	15	2.0
Education	Junior/senior high school	39	5.1
	Junior college	87	11.4
	College	547	71.5
	Master or above	92	12.0
Child	0	334	43.7
	1–2	413	54.0
	3 or above	18	2.4
Elder	0	313	40.9
	1–2	371	48.5
	3 or above	81	10.6
Permanent population of family	1	19	2.5
	2	69	9.0
	3	305	39.9
	4 or above	372	48.6
Permanent population of work	1	99	12.9
	2	417	54.5
	3 or above	249	32.5
Square of family housing	≤60	80	10.5
	60–90	211	27.6
	90–120	300	39.2
	120–150	116	15.2
	≥150	58	7.6
Adopting Household PV	No	765	100.0

Table 6. Reasons for not installing Household PV.

NO	Reason	Number of People	Proportion
1	Limited roof area	29	0.2293
2	Low household electricity consumption	159	0.2078
3	High installation cost	268	0.3503
4	Technology is insecure	79	0.1033
5	Do not understand Household PV	528	0.6902
6	Unwilling to take risks	93	0.1216
7	Insufficient government subsidies	123	0.1608
8	Not many people install Household PV around here	378	0.4941

5.2. Estimation Results

5.2.1. Attribute Parameter Analysis

Logit regression analysis was performed using Stata software 15.0. The regression analysis model was based on Household PV and the interaction between socio-economic characteristic variables and price. The final results for the coefficient estimates are shown in Table 7. Significant coefficients were obtained for the various Household PV attributes except for *Power* at the 1% level. The coefficient for this attribute was small and insignificant, suggesting that power is not a decisive factor in choosing Household PV products. As expected, the coefficient for the *Price* was significantly negative at the 1% level, implying that consumers tend to buy Household PV products at lower prices. We found a positive coefficient for the attribute, *whether it is a product in the Beijing-Tianjin-Hebei region*, indicating that consumers are more inclined to purchase products in the Beijing-Tianjin-Hebei region. A possible explanation for this is that transportation and installation of a product in the Beijing-Tianjin-Hebei region are more convenient. *The coefficient of whether additional lightening protection devices need to be purchased* was positive at the 1% significance level, suggesting that consumers prefer *lightening protection* devices rather than relying on the original devices. A positive coefficient was obtained for *Traceable information* at the 1% significance level, indicating that consumers are more inclined to purchase products than materials with the manufacturing process available to the public. Lastly, the coefficient for *After-sales service* was significantly positive, signifying that consumers tend to purchase products with more complete after-sales service.

Table 7. Regression results.

Var.	Coef.	Std. Err.
Price	−2.2655 ***	0.4871
Products	0.3218 ***	0.0612
Power	−0.0041	0.0341
Lightening protection	0.2036 ***	0.0648
Traceability Information [q]	0.4929 ***	0.0343
After-sales service [r]	0.8968 ***	0.0368
Cross terms with price		
Gen	0.1884 *	0.0983
Age	−0.0014	0.0638
Owner	0.0385	0.1156
Education	−0.0811	0.0757
Marriage	0.1451	0.1216
Usertype	−0.0076	0.1000
Size	−0.0465	0.0761
Child	0.1929 *	0.1009
Elder	0.0336	0.0767
Work	−0.0309	0.0804
Income	0.0241	0.0766
Square	0.0242	0.0481
Cons	−3.0588 ***	0.1354

Table 7. *Cont.*

Var.	Coef.	Std. Err.
Observations	8448	
Log-likelihood	−4080.0427	
Prob > chi2	0.0000	
Pseudo R^2	0.1396	

[q] for Traceability information, 1 represents "no traceability information", 2 represents "low quality (traceability information is incomplete)" and 3 represents "high quality (traceability information is complete)"; [r] for After-sales service, 1 represents "no after-sales service", 2 represents "low after-sales services" and 3 represents "high after-sales services". *** Statistically significant at the 1 percent level. * Statistically significant at the 10 percent level.

5.2.2. Calculation of WTP

In order to quantify the consumers' preference for the attributes of Household PV products, we calculated the WTP for each attribute. The monetary value that consumers are willing to pay for each attribute level increase can be expressed by the following formula:

$$WTP_{i|p} = \beta_i / \beta_{price} \tag{5}$$

In the formula, β_i and β_{price} represent the estimated parameter and price estimated parameter for $attribute_i$, respectively. Without considering the heterogeneity, we calculated the WTP of all the respondents at each attribute level to estimate the entire market.

Table 8 shows that the WTP differs significantly for the various attributes. Generally, consumers are willing to pay an additional USD 1420 for products in the Beijing-Tianjin-Hebei region, USD 2176 for products with better traceable information and USD 3959 for better after-sales service. However, consumers are not sensitive to the power increase. They are only willing to pay USD 18 to buy higher-power products: from the consumers' point of view, the increase in power will also lead to a price increase. Since Household PV is a consumer product, people are more inclined to choose "suitable power" than "higher power". Consumers are willing to pay an additional USD 899 for products that require additional lightening protection devices, which is contrary to our expectations. A possible explanation is that consumers reason that additional lightening protection devices can produce more safety. Comparing the WTP of the five attributes demonstrates that when consumers select products, they first prioritize the after-sales service, traceable information and whether products are available in the Beijing-Tianjin-Hebei region. Lightening protection devices and the products' power are considered lastly.

Table 8. The calculation results.

Attribute	Products	Power	Lightening Protection	Traceability Information	After-Sales Service
WTP	1420	18	899	2176	3959

The regression results in this study are compared with the findings of other related studies in Table 9. In this study, consumers had a strong preference for after-sales service for PV products, similar to the findings of Bao and Alsabbagh. Abdullah's study found that 41% of the respondents considered traceability information to be important in purchase decisions, and Hille found that there was 19.03% of the potential market share for local products. In this study, consumers were willing to pay a maximum of USD 3959 for the after-sales service attribute, which is lower than the findings of Radmehr, Yamaguchi and Su, in whose studies consumers were, respectively, willing to pay USD 6080, USD 8641 and USD 4725 for PV products/service. Scarpa's study found a lower WTP than the consumers' WTP for after-sales service in this study but higher than that for the other attributes.

Table 9. Comparison with the results of other studies.

Objectives		Average WTP in This Study	Relevant Conclusions in Reference Studies	Location	Reference
PV attributes	Products	USD 1420	19.03% of the potential market share for local products	Switzerland	Hille, S.L. et al. (2018) [48]
	Power	USD 18			
	Lightening protection	USD 899			
	Traceability Information	USD 2176	41% of respondents consider information to be important in purchase decisions	Pakistan	Abdullah et al. (2017) [66]
	After-sales service	USD 3959	Warranty service and after-sales reviews are of paramount importance	The USA	Bao, Q.F. et al. (2020) [67]
			21% of respondents believe that after-sales maintenance is important	Bahrain	Alsabbagh, M. (2019) [68]
PV products/service			WTP of 3% to 15% price premium	Italy	Bragolusi, P. et al. (2021) [26]
			WTP of EUR 6000 (USD 6080) (including subsidy)	North Cyprus	Radmehr, M. et al. (2014) [69]
			WTP of JPY 1.23 million (USD 8641)	Japan	Yamaguchi, Y. et al. (2013) [70]
			WTP of EUR 4663 (USD 4725)	Lithuania	Su, W.H. et al. (2018) [71]
			WTP of GBP 2831 (USD 3298)	Britain	Scarpa, R. et al. (2009) [72]

6. Discussion

To explore whether personal characteristics affected respondents' preferences for Household PV products, we included interaction terms between sociodemographic characteristic variables and price in the regression model (Table 7). As presented in Table 7, the coefficients of most cross-terms did not differ significantly from zero, except for *Gender* and *Number of minor children at home*. The findings indicate that these socio-economic characteristics impact the respondents' preferences for Household PV products. Next, we grouped the respondents by these two characteristics to analyze their impact on WTP for Household PV attributes. The group response analysis process was similar to the general analysis of our survey data.

6.1. The Influence of Gender on WTP

We introduced the *Gender variable* (male vs. female) to investigate whether differences exist in respondents' preferences for Household PV attributes. Table 10 presents the results of coefficient symbols of the male and female groups. Our results showed a significant difference in the *Power* coefficient between the two groups, indicating that males tend to buy high-power Household PV products, whereas women are inclined to buy low-power products, and given the coefficients, this tendency is very weak. The *Price* coefficients of both males and females were negative at the 1% significance level, indicating that both tend to buy products with lower prices. In addition, the male group's coefficient was negative for *Whether additional lightening protection devices need to be purchased* at the 1% significance level. However, this coefficient was insignificant in the regression analysis for the female group. These results show that men pay more attention to the product than women.

The samples were then grouped according to gender, and WTP was calculated for males and females. Table 11 presents the calculation results of WTP for Household PV attributes among the male and female groups. The results showed that women are more willing to pay higher prices for products in the Beijing-Tianjin-Hebei region. In contrast, men will pay more for additional lightening protection devices and complete traceable information. Men likely concentrate more on the nature and quality of products than women. In addition, both groups are willing to pay more for satisfactory after-sales service. However, neither is prepared to pay more for a higher-power product.

Table 10. Regression results by gender grouping.

Var.	Male		Female	
	Coef.	**Std. Err.**	**Coef.**	**Std. Err.**
Price	−1.6025 ***	0.1242	−2.3327 ***	0.1532
Products	0.2119 ***	0.0803	0.4748 ***	0.0949
Power	0.0408	0.0448	−0.0641	0.0528
Lightening protection	0.2772 ***	0.0851	0.1104	0.1001
Traceability information [s]	0.4695 ***	0.0450	0.5276 ***	0.0534
After-sales service [t]	0.8483 ***	0.0484	0.9669 ***	0.0570
Cons	−3.1219 ***	0.1796	−3.0017 ***	0.2079
Observations	4708		3740	
Log-likelihood	−2324.5953		−1746.8394	
Prob > chi2	0.0000		0.0000	
Pseudo R^2	0.1205		0.1677	

[s] for Traceability information, 1 represents "no traceability information", 2 represents "low quality (traceability information is incomplete)" and 3 represents "high quality (traceability information is complete)"; [t] for After-sales service, 1 represents "no after-sales service", 2 represents "low after-sales services" and 3 represents "high after-sales services". *** Statistically significant at the 1 percent level.

Table 11. Calculated WTP values by gender grouping.

Attribute	Gender	
	Male	**Female**
Products	1322	2035
Power	255	275
Lightening protection	1730	473
Traceability Information	2930	2262
After-sales service	5.294	4145

6.2. The Influence of the Number of Minor Children

We introduced the variable *Number of minor children at home* to determine whether this variable would impact the respondents' preferences for Household PV attributes. According to the questionnaire design, the respondents were divided into three groups: households without minor children, 1–2 minor children and three or more minor children. Table 12 shows the regression results of the coefficient symbols of the three groups. The *Price* coefficients of the three groups were negative, indicating that they all prefer lower-priced products. However, the price coefficient of the "three or above" group was insignificant, suggesting that the sample group was insensitive to the price because of the fewer samples. Similar to the study's overall results, the power coefficients were insignificant. The coefficients for *After-sales service and Traceable information* were positive for the three groups at the 1% significance level, indicating that respondents in these three groups tend to buy products with comprehensive after-sales service and traceable information.

The samples were also grouped according to the number of minor children in their family and the WTP was calculated. Table 13 presents the calculation results of WTP for Household PV attributes among the three groups. Due to the small number of samples for "three or above", we will only discuss the first two groups. The results show respondents with many minor children at home are more willing to pay for product origin and after-sales service than those without minor children. The latter is more willing to pay for additional lightening protection devices and traceable information. Families with minor children prioritized convenience and service. On the contrary, families without minor children pay more attention to the product.

Table 12. Regression results by number of minor children at home grouping.

Var.	0		1–2		3 or Above	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Price	−2.2626 ***	0.1547	−1.7081 ***	0.1266	−0.8267	0.5635
Products	0.3453 ***	0.0958	0.3030 ***	0.0814	0.4602	0.3842
Power	−0.0304	0.0533	0.0110	0.0455	0.0132	0.2102
Lightening protection	0.2539 **	0.1012	0.1855 **	0.0863	0.0379	0.4023
Traceability information [u]	0.5908 ***	0.0542	0.4150 ***	0.0457	0.6636 ***	0.2081
After-sales service [v]	0.9546 ***	0.0578	0.8625 ***	0.0490	0.7219 ***	0.2236
Cons	−3.1835 ***	0.2133	−2.9492 ***	0.1795	−3.6056 ***	0.8691
Observations	3680		4556		212	
Log-likelihood	−1723.4688		−2247.2131		−105.0579	
Prob > chi2	0.0000		0.0000		0.0022	
Pseudo R^2	0.1654		0.1214		0.1188	

[u] for Traceability information, 1 represents "no traceability information", 2 represents "low quality (traceability information is incomplete)" and 3 represents "high quality (traceability information is complete)"; [v] for After-sales service, 1 represents "no after-sales service", 2 represents "low after-sales services" and 3 represents "high after-sales services". *** Statistically significant at the 1 percent level. ** Statistically significant at the 5 percent level.

Table 13. Calculated WTP values by number of minor children at home grouping.

Attribute	Number of Minor Children at Home		
	0	1~2	3 or Above
Products	1526	1774	5567
Power	134	64	160
Lightening protection	1122	1086	458
Traceability Information [w]	2611	2430	8027
After-sales service [x]	4219	5049	8732

[w] for Traceability information, 1 represents "no traceability information", 2 represents "low quality (traceability information is incomplete)" and 3 represents "high quality (traceability information is complete)"; [x] for After-sales service, 1 represents "no after-sales service", 2 represents "low after-sales services" and 3 represents "high after-sales services".

The WTP values obtained in this study indicate that the respondents pay attention to these attributes when selecting products. However, it is difficult to compare the WTP values in this study with other WTP estimates because these values are only indicative. Most researchers calculate the WTP of Household PV as a unity. Nevertheless, the WTP values obtained were reduced due to the different group selections and attribute settings for comparison.

7. Conclusions and Policy Implication

7.1. Conclusions

This paper estimated consumers' willingness to pay for Household PV products and explored the factors that affect their product selection. For this purpose, we first applied a discrete choice model that combined six product attributes of Household PV to design 16 sets of attributes. Subsequently, we conducted a questionnaire survey of 765 urban and rural residents without installing Household PV systems in Tianjin, China. The respondents' attribute preferences and WTP were then analyzed using a logit regression model. Finally, we analyzed the influence of respondents' socio-economic characteristics on WTP. The main findings of the study are as follows:

(1) Public environmental awareness remains high; thus, people anticipate using more energy-efficient and environmentally friendly products. However, the low proportion of participants without an installed Household PV system shows that there is still a large gap between intention and action. The main reasons for not installing PV products include the incomprehension of Household PV products and the impact on people in their communities.

(2) Consumers are highly concerned about the price of PV. Products with relatively low prices are more acceptable to them. In addition, the nearby region, better lightening protection devices, clear traceable information and better after-sales service positively impact consumers' choice of Household PV products. However, the products' power does not significantly affect their choice.
(3) Consumers' willingness to pay for after-sales service (3959 USD/level) is the highest, and they also have a remarkable preference for traceable information (2176 USD/level). On the contrary, lightening protection devices and the products' power does not make consumers pay more for products. Socio-economic characteristics, such as gender and the number of minor children at home, significantly impact consumers' PV-adoption behaviors. Men and women have different willingness to pay for different product attributes, and consumers with no minor children at home will pay more attention to the product.

7.2. Policy Implications

With the continuous development of the economic society, consumer electricity demand is increasing in China. The decline in nonrenewable energy forces consumers to consider alternative energy options. Thus, Household PV systems are favored by consumers because they are the preferred product for family investment and can achieve "self-production and self-consumption". Household PV plays an essential role in reducing extra social expenses. Its overall popularity and application have become an inevitable trend. Current policies encourage people to actively use renewable energy to generate electricity and contribute toward building an environmentally friendly society and development strategy. However, the price subsidy of Household PV products is decreasing each year, which impacts consumers' purchases and installation. Changes in consumer demand have put forward new requirements for corporations and governments. Therefore, the rationality of Household PV pricing and relevant policy making is becoming increasingly important. The policy recommendations are as follows:

According to the results, public environmental awareness remains high, indicating people plan to use more energy-efficient and environmentally friendly products. However, the low proportion of participants without an installed Household PV system shows that there is still a large gap between intention and action. The main reasons for not installing PV products include the incomprehension of Household PV products and the impact on people around them. Therefore, enterprises and the government highly prioritize publicity. The government has more advantages in promoting the installation of Household PV products and strengthening the publicity and promotion of such products due to its authority, reliability and supporting initiatives. In order to make it easier for consumers to understand the principles and environmental benefits of household photovoltaics, the government could popularize scientific knowledge about climate change and a low-carbon lifestyle to residents through advertising slogans and expert lectures with the help of media platforms such as TV and the internet.

In addition, the government and enterprises should work independently to effectively realize the widespread application of Household PV systems. The government could gradually promote the subsidy reduction policy to make consumers less sensitive to price. At the same time, the public should actively understand and accept the new product from an environmental protection point of view. The government could fully consider residents' needs and formulate policies regarding local conditions. For poor areas and those without adequate sunlight, more subsidies and preferential policies could increase the appeal of Household PV products to price-sensitive consumers. The government could adhere to the collaborative promotion of the "Carbon Peaking and Carbon Neutrality" (Reference: "Implementation Plan for Carbon Peaking and Carbon Neutrality Supported by Science and Technology 2022–2030"—The State Council and the Twentieth National Congress of the CPC on 16 October 2022) policy goals and the rural revitalization strategy. The government could strengthen technical support and services for installing Household PV systems in rural areas while gradually promoting home photovoltaics as an alternative to traditional energy sources. The government could encourage nearby residents to observe the practical effects of Household PV products to reduce their psychological and economic concerns.

On the other hand, from the corporates' point of view, the WTP value is high for after-sales service. People will consider choosing more expensive products for better services. Enterprises should consider improving after-sales service levels to realize the complete application of renewable energy products such as Household PV systems. Installation and free warranty services (for several years) are feasible. Satisfactory after-sales service provides a guarantee when purchasing products. At the same time, considering that Gender and the Number of minor children at home significantly impact the price respondents are willing to pay for Household PV products, they can segment the market according to the above two attributes. For men, more emphasis is placed on the quality of the product itself, such as lightening protection devices and traceable information, while women focus more on the information about the product's convenience and service. Calculating the WTP values, the results showed that the same consumer might have a different WTP for each attribute of Household PV. In addition, corporations can emphasize the product's origin and after-sales service to families with several minor children while focusing on complete traceable information and convenient service to families with relatively few minor children.

7.3. Limitations

Our study provides empirical evidence about consumers' WTP for Household PV products and supports the existing literature that the attributes of renewable energy products influence consumers' choices. Although this paper has provided valuable results, there is still room for research improvement of consumers' WTP for Household PV products due to the complexity, uncertainty and exploratory nature. Future studies could expand the geographical scope (e.g., other provinces) and increase the study's sample size to validate our findings further. Moreover, future work could analyze the dynamic relationship between WTP and product attributes based on panel data from tracking surveys. Due to the discrepancy between WTP values obtained in this study and those of other studies, the comprehensiveness of the focused attributes is subject to further debate. Lastly, based on our country's current system and investment costs, further research is needed to study consumers' preferences for renewable energy and explore factors for increasing consumers' purchasing power.

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