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Consumers' Preferences and Derived Willingness-to-Pay for Water Supply Safety Improvement: The Analysis of Pricing and Incentive Strategies

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Abstract: With increasing water supply accidents and higher water demand, urban water supply safety (WSS) remains a crucial public policy issue in developing countries. The purpose of this paper is to investigate consumers' willingness-to-pay (WTP) and their preferences to improve WSS in China, to support governments in water regulation policy design and water providers in investment-decisions. A discrete choice experiment method with the consideration of not only attributes of WSS but also attitudinal and demographic variables have been adopted to assess consumers' WTP and preferences for WSS improvement. The results show that Chinese urban residents are willing to pay a significantly higher price for improved WSS. Demonstrated marginal mean WTP for the change of the attributes range from 0.18 RMB/m^3 (0.03 USD/m^3) (1 RMB was around 0.154 USD in 2016) for decreased water supply interruption to 2.33 Yuan RMB/m^3 (0.35 USD/m^3) for improved drinking water quality. Investments in water processing facilities and water distribution networks should come first. Cross-subsidy concerning different developing districts is the most efficient policy instrument. The study contributes to the recent literature not only by introducing attitudinal variables in choice experiment survey in water supply field, but also by revealing the correlation of choice modeling applications in WSS improvement programs.

Keywords: water supply safety; discrete choice experiment; consumer preference; willingness-to-pay (WTP); pricing policy

1. Introduction

While drinking water supply may be gradually popularizing worldwide, for many developing and less developed countries, water supply safety is still the fundamental concern [1]. Water supply safety (WSS) can be defined as the ability to supply a constant flow of drinking water with specific quality and pressure in specific operating conditions at any or a particular time and at an acceptable price [2]. Under the safety condition, tap water should meet the Standards for Drinking Water Quality to ensure public health and to avoid water related illnesses.

In recent years, ongoing drinking water supply scandals have emerged in China [3]. To guarantee water supply safety, higher Standards for Drinking Water Quality (GB5749-2006) with stricter requirements for drinking water were published on 1 July 2012 in China. (In the new Standards for Drinking Water Quality (GB5749-2006), detection indexes have been expanded to 106 items from

35 items. The new one makes stricter demand on organics, microorganisms and disinfection. This is the first time a developing country has implemented strict regulations on drinking-water quality and the first time the same standards have been applied in rural and urban areas in China) However, several Chinese water companies are having difficulties in meeting the new standards due to the outdated treatment facilities and distribution networks [2]. Furthermore, the growth of economic activities has degraded the water resources generated [4]. It is urgent to raise investment capital for upgrading water treatment facilities and distribution networks to improve WSS [5].

The stakeholder analysis by Wang et al. [6] indicates that water companies, governments and consumers are the most important and definitive stakeholders in water supply systems in China. Wang et al. [2] developed a game theoretical model between government and a water company to analyze the strategy for improving water supply safety. Theoretical and numerical analysis concluded that water price is the effective policy to optimize critical stakeholders' strategies. To accomplish the goal that government fully carries out policy and for water companies to improve iteratively, the price difference between the unit upgrading cost of water company and the that cost shared by the government should be less than or equal to the water price increase. Thus, water price should be adjusted to meet the need of WSS improvement.

In China, the water price consists of four elements, set by different authorities but integrated in one water price to be collected by either the water company or the water resource authority. Of those four elements, the water resource authorities at provincial level decide the rates of water resource fees and raw water price, while the urban construction authorities at municipal level regulate the water supply price and wastewater treatment charges [7]. As a result, governments still play a leading role in water pricing decisions. In addition, China is self-sufficient in water resources. Chinese water pricing is barely affected by other changes in the global market. The major challenges in the current water pricing are to cover the costs of WSS improvement and to meet the domestic consumers' preferences on WSS [6]. Efficient and sustainable water pricing should be based on a thorough understanding of consumers' preferences on their cost bearing attitude toward water supply safety. The analyses of consumers' willingness-to-pay (WTP) to improve WSS are hugely demanded by policymakers and other authorities responsible for enhancing WSS.

This study is designed to conduct a comprehensive exploration of consumers' willingness-to-pay and preferences to improve WSS by following and seeking to contribute to previous studies on water supply management. The research questions in this paper include: (1) What is the mean WTP to improve WSS? (2) What are the main factors influencing consumers' WTP? (3) What are the implications for stakeholders and decision-makers of this estimate? The answers to these research questions are beneficial to local and central governments for future water regulation policy design as well as water providers for investment decisions.

2. Theoretical Framework

Discrete choice experiment (DCE), drawing upon Lancaster's theory of value, are attribute-based, requiring attributes and corresponding levels of the good being valued to be defined [8]. Since drinking water is a typical complex good which can be decomposed into several attributes [9], DCE method is suitable to investigate consumers' WTP and their preferences to improve WSS. In the context of water supply management, many discrete choice experiment (DCE) studies have investigated preferences over various water supply attributes that can affect consumers' benefits [10–12]. For example, Latinopoulos [13] designed and carried out a choice experiment aiming at evaluating consumers' preferences for the comparison level for alternative water supply attributes, such as water quality, frequency of water supply cut off and water availability. Since water supply safety is a typical complex condition which can be decomposed into some attributes, the consideration of consumers' preferences of WSS was incomplete in previous studies. The attributes selected in the previous studies were focused on residents' WTP to water quality. The existing research does not explore preferences regarding water supply safety as integral. In addition, existing DCE studies have found that there are considerable differences in preferences regarding drinking water with respect to demographics [1,14–16]. Thus, this study examines the impact of consumers' socio-demographic characteristics such as education and family composition on WSS. Furthermore, consumers' attitudes, which are very important for consumers' preferences for WSS, are also considered. This paper fills up the research gap by choosing attributes according to the context of water supply safety. Various factors which are related to consumers' preferences for WSS are investigated, including socio-demographics and attitude factors. This is the first large-scale study that examines consumers' preferences for WSS in China using a DCE approach.

2.1. WSS Attributes and Levels

The first stage of the study was determined to make a suitable selection of attributes. Before designing the choice sets for this study, a broad review of water supply system and management literature was conducted aiming at identifying the characteristics of WSS improvement. The relevant attributes include water price [17,18], interruption to supply [10,13,19] and drinking water quality [10,13]. In addition, two attributes were specifically included as water supply pressure and water supply service. Since water supply pressure is frequently unstable many urban regions in China, it would stand to reason that water supply pressure might influence consumers' WTP and preferences for WSS. In the light of Hensher's research [18], knowledge of water supply process or relative policies are considerable for consumers. According to the definition of WSS, five attributes were ultimately chosen to describe WSS improvements in this study: drinking water quality (QUALITY), frequency of water supply interruptions (INTERRUPT), water supply pressure (PRESSURE), water supply service (SERVICE) and additional payment in water consumption charge (PRICE). All the attributes and their definitions are presented in Table 1.

Table 1. Selected attributes and levels of DCE.

Attributes	Definitions	Levels	Coding
INTERRUPT	Frequency of water supply temporary interruptions (i.e., average number of occurrences during a year)	Frequent occurrence (no less than 3 times per year) *	0
		Rare occurrence (equal or less than 3 times per year)	1
PRESSURE	Stability of tap water supply pressure	Unstable, insufficient in the peak period *	0
		Stable all the time	1
QUALITY	Quality of the tap water (expressed in terms of the number of samples failure to meet the required Standard for Drinking Water Quality)	Maintain current water quality but it might fail to meet the standard sometimes *	0
		Improve drinking water quality to meet the standard all the time	1
SERVICE	Water supply services including maintenance and information	Delayed maintenance or insufficient information *	0
		In-time maintenance and comprehensive information	1
PRICE	Increase in unit water price	0 RMB/m^3 *	continuous
		0.5 RMB/m^3	
		1.0 RMB/m^3	
		1.5 RMB/m^3	
		2.0 RMB/m^3	

Note: * indicate the status quo level.

The next stage in the DCE method was to identify the levels of the selected attributes. This study relied on focus groups with 10 participants for the elicitation of a sufficient definition and explanation of the attributes to be estimated for the city of Shenzhen. Shenzhen is the first and one of the most successful Special Economic Zones in China, which shares a boundary with Hong Kong. However, the water supply safety is still a concern for local government because of the unequal development of Shenzhen's ten administrative sub-districts. Some districts outside of the original special economic zone are still developing with more water supply safety concerns. Therefore, the focus group members were managers and employees from Shenzhen Municipal Water Affairs Bureau and Shenzhen Water Affairs Group Limited, representatives from China Urban Water Association, and urban residents and professionals in Shenzhen. Focus groups were also helpful in assessing respondent reaction to the range of attribute levels considered in choice scenarios. While experts from Municipal Water Affairs Bureau and Water Affairs Group Limited suggested that attribute levels should be divided quantitatively, residents showed that they could hardly understand the detailed expression of attribute levels. The levels of choices were presented in qualitative forms for the reason of uncertainty over the changes in attribute features.

Water supply quality was taken for a qualitative attribute. The quality attribute was divided into two levels: current water quality may fail to meet the standard sometimes (status quo) and improved drinking water quality to meet the new Standards for Drinking Water Quality (GB5749–2006) all the time. This simple classification was considered to be applicable because of the difficulty for respondents to assess drinking water quality by means of its physicochemical properties (e.g., smell and taste) with uniform standard. Frequency of water supply interruptions was also regarded as a qualitative attribute. The frequency attribute was defined as the number of times that water supply cut off in a household during a year. It was divided into two levels: rare occurrence (>3 times/year) and frequent occurrence (≤3 times/year). Two qualitative levels of stability of water supply pressure were unstable and insufficient in the peak period (status quo) and stable all the time. The attribute of water supply service included maintenance service and information service with two different levels delayed maintenance or insufficient information service (status quo) and improved service with on-time maintenance and comprehensive information provided. With better water supply service, water supply facilities (e.g., water tank and second water reservoir) would be cleaned and maintained on-time. Meanwhile, consumers would get comprehensive and timely information about water supply safety. The increase in unit water price was used as a payment vehicle in this study because it was easily understood by Chinese respondents. A pre-survey with questions on payment card was designed for 100 urban residents to find the identification of the level of PRICE. Finally, the attribute of cost contained five levels: increases of 0, 0.5, 1.0, 1.5 and 2.0 RMB/m^3. The attribute-level specifications for the choice experiment are also summarized in Table 1.

After the identification of the attributes and the levels, the next step was to combine the attribute levels to raise alternative scenarios and require the respondents to choose the option they give preference to from a choice set. A fractional factorial experimental design to identify the combinations of attributes and options in a choice set was implemented [20]. This study obtained 16 pairs of central effects of disparate WSS improvement options through an orthogonal trial of the integrated factorial design by using experimental design technique [21] in SPSS. Among the 16 combinations, one combination represents the status quo and three combinations are impractical (improved WSS without any cost). While using the status quo combination as the baseline, two other combinations were randomly chosen from the other 12 combinations. Thus, 66 profiles (C_{12}^2) were obtained at last. Each of the profiles includes three alternatives. However, 50 profiles were finally obtained after dropping the incredible combinations. One of the choice sets is shown as an example in Table 2. The individuals surveyed were asked to make their choice of preference and then present on each card, which comprises alternatives a and B and "status quo". Alternatives a and B represent the improved water supply situation with different WSS improvement. The status quo option served the current water supply situation without any WSS improvement measurements.

Table 2. Example of preference set card handed out to respondents.

Attributes	Option A	Option B	Status Quo
INTERRUPT	Rare (≤3 times/year)	Often (>3 times/year)	often (>3 times/year)
PRESSURE	Stable all the time	Unstable in the peak period	Unstable in the peak period
QUALITY	Meet the standard all the time	Meet the standard all the time	Failed to meet the standard sometimes
SERVICE	Delayed maintenance or insufficient information	In-time maintenance and comprehensive information	Delayed maintenance or insufficient information
PRICE	1.0 RMB/m^3	2.0 RMB/m^3	0
Your Choice	☐	☐	☐

2.2. Variable Explanation

It is justified to expect that factors unrelated to product may affect the choice of a special alternative [22]. Besides the attributes above, this study specifically considered some individual characteristics involving consumers' attitude about WSS and socio-demographic variables. The study of Hansla et al. [23] investigated consumers' priority on green energy by CVM and concluded that willingness-to-pay increased with a good attitude to green energy. Angulo and Gil [24] figured that consumers' decisions on food purchases are influenced by their health concerns. Pino et al. [25] proved that favorable attitudes towards water saving measures influence farmers' intentions to adopt water saving measures. Krystallies and Chryssohoidis [26] showed that consumers' trust of the authorities and certification would have an impact on their WTP for organic food. Furthermore, recent research suggests that consumers' WTP is also related to the knowledge of supply process [27,28]. Accordingly, consumers' perceptions and attitudes about WSS were analyzed in this study. Concern on WSS (CON), attitude towards WSS improvement project (ATT), trust in authorities (TRU) and information disclosure (INF) were included. The attitude variables and their descriptions are listed in Table 3. CON represents respondents' attention and awareness of water supply safety. In this study, CON is measured by a ranking scale. The more concern about WSS, the lower value of CON is. INF means the level of information available for respondents. INF and TRU are measured by five-point Likert scale. The relations of demographic factors for consumers' WTP and preferences were also investigated (shown in Table 3).

Table 3. Descriptions and statistics of demographic variables.

Variables	Descriptions	Mean
CON	The level of perception on WSS (10 = not concern at all, 1 = highly concern)	4.031
ATT	Consumers' attitude to WSS improved project (1 = support, 0 = otherwise)	0.767
TRU	The degree of consumers' confidence in the authorities (5 = quite trust, 1 = not trust at all)	3.186
INF	The degree of information disclosure on WSS (5 = sufficient disclosure, 1 = no disclosure)	2.789
GENGER	gender (male = 1, female = 0)	0.55
CHILD	the numbers of children in the household (at least one child under 13-year-old = 1, otherwise = 0)	0.45
Age		
AGE1	no more than 30 years	64.44%
AGE2	31–40 years	25.87%
AGE3	41–50 years	5.72%
AGE4	no less than 50 years	4.97%
EDU		
EDU1	Associate degree or lower	32.89%

Table 3. *Cont.*

Variables	Descriptions	Mean
EDU2	Bachelor degree	46.27%
EDU3	Master degree or above	21.14%
INC	Personal monthly income	
INC1	No more than 3000 Yuan	20.40%
INC2	3001–6000 Yuan	33.33%
INC3	6001–10,000 Yuan	30.85%
INC4	10,000 Yuan or more	15.42%
Sample size	388	

3. Statistical Models

3.1. Theoretical Models

Random utility theory and the Lancaster's model of consumer choice built up a theoretical basis on the DCE method [29]. Based on utility theory, there are implicit assumptions about individual preferences, including completeness, transitivity and convenience [30]. A deterministic and a random component based on the random utility theory are included in the conventional utility function. While the random component indicates those factors of separate choice interacted but unobserved, the deterministic component involves factors observed by the researcher. Thus, the utility U associated with individual n who choose alternative i is given by:

$$U_{in} = V(X_{in}) + \varepsilon(X_{in}) \quad (1)$$

where X is the vectors of attributes, $V(\cdot)$ represents the deterministic component and $\varepsilon(\cdot)$ represents the error component. The probability of individual n choosing alternative i from a set of alternative J could be valued using conditional logit (CL) model. The estimated probability is:

$$\mathrm{Pr}_{in} = \frac{\exp[V(X_{in})]}{\sum_{j=1}^{J} \exp[V(X_{in})]} \quad (2)$$

where exp(·) means exponent utility. If $V(\cdot)$ is assumed as a linear function with identically and independently distributed (IID) random error term and a type I extreme value (Gumbel) distribution, the indirect utility function is:

$$V_{jn} = \beta_0 \times \mathrm{ASC} + \sum\left(\beta_{jk} \times X_{jk}\right) + \sum \varphi_{jk}(S_n \times \mathrm{ASC}) \quad (3)$$

where ASC is an alternative specific constant which captures the utility specifically to the status quo. ASC, which was designed as a dummy, was equal to 1 if respondents choose either improved alternative of WSS or 0 otherwise. X_{jk} is the k characteristic value of the choice j; β_{jk} is the parameter allied to the k characteristic; S_n is the socio-economic characteristics vector of individual n; and Φ_{jk} is the vector of the coefficients related to the individual socio-economic characteristics. In this study, ASC is regarded as a parameter for a special alternative expressing the role of unobserved sources of utility. It has been argued that ASC is crucial for purpose of interpreting the preferences of the individuals [31]. Due to its sign, ASC has been interpreted as a status quo bias or endowment effect or as a utility premium for moving away from the status quo [32].

The IIA (Independence of Irrelevant Alternatives) assumption of CL model fails to hold with the possible existing preference heterogeneity, thus results in biased estimations [33]. However, the mixed logit (MXL) model does not require the IIA assumption [34]. Since the MXL model accounts for the unobserved heterogeneity, the utility function is:

$$U_{in} = \mathrm{V}(X_n(\gamma + \delta_i)) + \varepsilon(X_n) \tag{4}$$

where γ is a parameter which varies by random component δ due to preference heterogeneity across individuals. The probability of individual n choosing alternative i from a set of alternatives J can be estimated as MXL model:

$$\mathrm{Pr}_{in} = \frac{\exp[V(X_n(\gamma + \delta_i))]}{\sum_{j=1}^{J} \exp[V(X_n(\gamma + \delta_i))]} \tag{5}$$

Considering the preference deviations, the indirect utility function is:

$$V_{jn} = \beta_0 \times ASC + \sum\left(\beta_{jk} \times X_{jk}\right) + \sum\left(\iota_{nk} \times X_{jk}\right) + \sum \varphi_{jk}(S_n \times \mathrm{ASC}) \tag{6}$$

where τ represents a vector of deviation parameters. The estimated coefficients of mean preference values β are taken to be either log-normally or normally distributed. The individual tastes τ_{nk} are assumed to be constant over all choices but vary from one respondent to another.

When the cost of choosing an option is involved as an attribute, the part-worth price can be estimated by marginal rate of substitution. The part-worth price of an attribute j can be calculated by:

$$\mathrm{WTP}_j = -1 \times \left(\beta_i / \beta_{price}\right) \tag{7}$$

Lastly, compensating surplus (CS) can be estimated to reveal the diverse WSS improvement plans related with variation in attributes. CS could be calculated shown in Equation (8) where V_{i0} is the indirect utility component associated with the status quo and V_{i1} is the indirect utility component associated with an improved scenario, while β_{price} is the marginal utility of cost.

$$\mathrm{CS} = -\frac{1}{\beta_{price}} \times \left(\ln \sum_i \exp(V_{i0}) - \ln \sum_i \exp(V_{i1})\right) \tag{8}$$

3.2. Econometric Models

In this study, both conditional logit (CL) model and mixed logit (MXL) model were applied. Two functional forms of the utility function with basic model and interaction model were considered.

Firstly, basic model was analyzed to present the explanation designed attributes made on the choice of varying alternatives in a choice set. The explanatory variables included in the basic CL and MXL models were INTERRUPT, PRESSURE, QUALITY, SERVICE, PRICE and the ASC. The indirect utility function was supposed to be a linear function of the five choice attributes. The utility function of individual n choosing choice set i was used as:

$$\begin{gathered} V_{\mathrm{in}} = \beta_0 \cdot \mathrm{ASC} + \beta_1 \cdot \mathrm{INTERRUPT_{in}} + \beta_2 \cdot \mathrm{PRESSURE_{in}} \\ + \beta_3 \cdot \mathrm{QUALITY_{in}} + \beta_4 \cdot \mathrm{SERVICE_{in}} + \beta_5 \cdot \mathrm{PRICE_{in}} \end{gathered} \tag{9}$$

where β are the parameters of choice attributes to be estimated.

To analyze the mean WTP for WSS improvements, socio-demographic variables and attitude variables were included as interaction terms with ASC. The following form was then used in the interaction models for both CL and MXL models:

$$\begin{aligned} V_{\text{in}} = \beta_0 \cdot \text{ASC} + \beta_1 \cdot \text{INTERRUPT}_{\text{in}} + \beta_2 \cdot \text{PRESSURE}_{\text{in}} + \beta_3 \cdot \text{QUALITY}_{\text{in}} \\ + \beta_4 \cdot \text{SERVICE}_{\text{in}} + \beta_5 \cdot \text{PRICE}_{\text{in}} + \beta_6 \cdot \text{ASC} \times \text{CONCERN} + \beta_7 \cdot \text{ASC} \times \text{TRUST} \\ + \beta_8 \cdot \text{ASC} \times \text{ATTITUDE} + \beta_9 \cdot \text{ASC} \times \text{INFOR} + \beta_{10} \cdot \text{ASC} \times \text{GENDER} \\ + \beta_{11} \cdot \text{ASC} \times \text{CHILD} + \beta_{12} \cdot \text{ASC} \times \text{AGE} + \beta_{13} \cdot \text{ASC} \times \text{EDU} + \beta_{14} \cdot \text{ASC} \times \text{INC} \end{aligned} \tag{10}$$

In Equation (10), the socio-demographic and attitudinal variables were modeled through the interactions of the variables with the ASC. A statistically significant and positive partial coefficient of the interaction between any variable and ASC shows that the variable generates a higher probability that respondents will choose the improved options, whereas a negative partial coefficient shows a higher probability that respondents will choose the status quo.

4. Survey and Data

4.1. Survey Design and Implement

The survey was designed to be separated into four parts. The first one is an introduction to present the objectives and a detailed description of each attribute and its levels. After introduction, the second part assessed and explored consumers' perceptions and attitude on WSS by asking respondents their level of Concern on WSS (CON), attitude to WSS improvement project (ATT), trust in authorities (TRU) and information disclosure (INF). The third part presented the choice experiment. Each participant was required to perform the DCE section by making a choice between the three available options for each of the five attributes. The last part focused on the demographic factors of respondents. To make answering convenient, all questions were set in multiple-choice format.

The questionnaire was pretested and optimized to account for respondents' comprehension of the choice tasks, the adequacy of the number of options, attributes and levels. In the first step, 25 interviews were carried out during November–December 2013. At the end of December 2013, an Internet pre-test was conducted with 50 respondents. Finally, an online survey was carried out from March to May 2014 of Shenzhen, China.

4.2. Sample Characteristics

A sample of 447 surveys was submitted. However, 59 surveys were eliminated because of uncompleted answers or suspected unreal answers. The rationality tests of the other data was verified. The final sample consisted of 388 individuals, which contained three options, thus offered a total of 58,200 ($388 \times 50 \times 3$) valid observations for the choice model estimations.

A review of demographic characteristics and attitude variables is shown in Table 3. In this survey, 46% of the respondents are male and 58.71% are aged in 21–30 years old. Nearly half of the respondents have more than one child in their households which is consistent with the situation of Guangdong Province where many families have more than one child. Consistently, the city statistics for Shenzhen shows that the average age of consumers in Shenzhen was 33.6 years old, while the average individual monthly income was 7261 RMB in 2013. Therefore, the sample showed appropriate representation. According to the statistics, the respondents are paying attention on urban WSS. Nearly 80% of respondents showed the support for WSS improvement projects. The average value of the trust in authorities is 3.19. According to the value of information disclosure, it is revealed that the respondents are not familiar with the knowledge of water supply processes.

5. Result

5.1. Estimate Results of CL and MXL Models

The choice experiment resulted from conditional logit (CL) and mixed logit (MXL) models are presented in Table 4.

For CL models, the overall fit of the model tested in this study is given by the likelihood ratio test (LRT) and the pseudo R^2. The models are highly statistically significant. When the pseudo R^2 value for basic model and interaction model are made comparison, the results indicate a higher level of parametric fit for the latter (pseudo R^2 = 0.2440) compared to the former (pseudo R^2 = 0.2069). Because the failure of IIA assumption in CL models may lead to misspecification, the Hausman and McFadden (1984) test for the IIA property was conducted. The likelihood ratio tests were conducted for four distinct subsets of all the choice alternatives for the purpose of ascertaining whether the IIA holds. Referring to the estimations, the IIA property was rejected at 1% significance level for the four CL subset models. Therefore, the effectiveness of the CL models was proved.

The MXL models with 1000 random draws were also applied to address some limitations of the standard CL model such as homogenous preferences and the IIA assumption. To make sure that standard deviations (SD) can change in sign overall the entire model, all other attributes were estimated to be normally distributed and random. It is assumed that the increase in unit water price was specified as non-random. Likelihood ratio test was conducted to compare the CL interaction model and the MXL interaction model. The results rejected the null hypothesis. It is concluded that the CL model is not nested in the MXL model. It is proven that preference heterogeneity exists. Therefore, the MXL model is more applicable than the CL model to analyze the survey data in this study.

All results are shown in Table 4. In both CL and MXL basic models, all attributes emerge as significant determinants of choice ($p < 0.001$). Based on the results of this study, all utility function parameters have theoretically consistent signs. As expected, the positive sign of QUALITY represents the positive attitude of the respondents that they prefer to improve drinking water quality to ensure high standard consistently (i.e., individuals are more likely to choose alternatives with better water quality). This is also the case for the attribute INTERRUPT, representing that people are better off when experiencing fewer water supply interruptions. The positive sign of PRESSURE shows that respondents have positive preference to improve the stability of water supply pressure. According to the positive sign of SERVICE, there is a positive utility for respondents to improve water supply service. Thus, respondents prefer enhanced quality of treated drinking water, decreased frequency of water supply interruptions, stable water pressure and better water services. The MXL models reveal significant standard deviations for the four attributes' coefficients ($p < 0.001$). This means that residents have heterogeneous preferences over INTERRUPT, PRESSURE, QUALITY and SERVICE at 1% significance level. The sign of the payment vehicle attribute indicates an increase in unit water price is negative, as expected. Since the ASC coefficient is positive and statistically significant, it results that a positive utility impact appears in any change from the status quo. Therefore, ceteris paribus, residents prefer to increase the unit water price for improved WSS.

Clearly, the interaction models have better goodness of fit than the basic models, as stated by the LRT and the Pseudo R^2 values. However, the attribute signs and coefficients were found to be quite similar to the basic models. According to the attitudinal variables, the coefficients of all estimated interactions are statistically significant and plausible. A negative sign of CONCERN indicates that respondents who paid more attention to WSS had a higher likelihood of choosing improved option. Similarly, ATT, TRU and INF all have highly significant influence on choices. The results show that supportive respondents in WSS improvement project are more likely to choose improved options. The respondents who express more trust in the related authorities (e.g., water companies and government) tend to choose improved option. Respondents' WTP to improve WSS is positive with information disclosure on WSS.

Table 4. The results of conditional logit and mixed logit estimations.

Variables	CL Model		MXL Model	
	Basic	Interaction	Basic	Interaction
Mean effect				
INTERRUPT	0.1844 *** (0.0234)	0.1945 *** (0.0236)	0.2691 *** (0.0640)	0.2177 *** (0.0606)
PRESSURE	0.6865 *** (0.0250)	0.7085 *** (0.0252)	1.1045 *** (0.0622)	1.0515 *** (0.0586)
QUALITY	1.6448 *** (0.0273)	1.7090 *** (0.0279)	2.8025 *** (0.1131)	2.7697 *** (0.1058)
SERVICE	0.2734 *** (0.0236)	0.3021 *** (0.0239)	0.2133 *** (0.0827)	0.3360 *** (0.0468)
PRICE	−0.7171 *** (0.0219)	−0.7708 *** (0.0223)	−1.2000 *** (0.0288)	−1.1887 *** (0.0287)
ASC	0.4010 *** (0.0390)	1.3267 *** (0.2133)	0.9726 *** (0.0498)	1.2693 ** (0.3559)
ASC × CON		−0.0515 *** (0.0092)		−0.0340 ** (0.0172)
ASC × ATT		0.8130 *** (0.0533)		0.4280 *** (0.0901)
ASC × TRU		0.2746 *** (0.0304)		0.2573 *** (0.0455)
ASC × INF		0.1833 *** (0.0274)		0.1407 *** (0.0455)
ASC × GENDER		−0.3342 *** (0.0447)		−0.4441 *** (0.0842)
ASC × CHILD		−0.0872 (0.0539)		−0.2978 (0.0993)
ASC × AGE1		−0.3814 ** (0.1922)		−0.9479 *** (0.2846)
ASC × AGE2		0.1828 (0.1959)		−0.7506 *** (0.2876)
ASC × AGE3		−0.2493 (0.2030)		0.3558 (0.3047)
ASC × EDU1		0.4449 *** (0.0643)		0.6674 *** (0.1253)
ASC × EDU2		0.1944 *** (0.0612)		0.7497 *** (0.1111)
ASC × INC1		0.0611 (0.0967)		−0.2816 *** (0.1472)
ASC × INC2		−0.2837 *** (0.0859)		−0.5897 *** (0.1332)
ASC × INC3		−0.5724 *** (0.0818)		−0.9667 *** (0.1282)
Standard deviation effects				
INTERRUPT			1.1872 *** (0.0562)	1.0083 *** (0.0444)
PRESSURE			1.021 *** (0.0544)	0.9478 *** (0.0560)
QUALITY			2.8350 *** (0.1118)	2.1622 *** (0.0654)
SERVICE			1.5601 *** (0.0661)	1.2186 *** (0.0449)
Log-likehood	−16,903.36	−16,112.01	−12,432.68	−12,333.84
Wald chi^2	6685.78	7403.68		
Pesudo-R^2	0.2069	0.2440		
LR Chi^2			8359.63	7556.33
Observations	58,200			

Note: *** significant at 1% level; ** significant at 5% level; * significant at 10% level; standard deviations are in parentheses.

Since the socio-economic variables do not change over choice cases, they interacted with the alternative specific constant. In the MXL international model, the econometric analysis identifies some population groups with a higher propensity for improved WSS. The models reveal that gender, income and education level have significant impact on choices. The coefficient of the interactional gender indicates that there is a higher probability that women will choose improved scenarios. As expected, among the eldest individuals with highest education level, those higher-income respondents are relatively more likely to pay for increase in unit water price. However, among the respondent group with both higher income and age level, those respondents with lower education are willing to pay more for improved WSS. The reason for this could be that, among this population group, those with higher income and lower education level, being older, might be native Shenzhen residents living in less developing districts in Shenzhen, thus they might experience more water supply accidents. This implies that they should be willing to pay more. In this study, having a child in their household shows no significant impact on consumers' choices. However, among the population group of individuals with highest education and income level, the youngest people would pay less for improved WSS. This is consistent with the fact that many young, but educated with highest income residents in Shenzhen live in more developed districts where less water supply accidents occur.

5.2. Implicit Prices and Compensating Surplus

The MXL model with interactions was found to be the best from the above explanations. Therefore, further analysis on econometrics involved only the MXL model with interactions. The average implicit prices of the four attributes are shown in Table 5. Krinsky and Robb's (1986) bootstrapping procedure was conducted to evaluate the implicit prices and the respective 95% confidence intervals.

Table 5. Implicit price and confidence interval (unit: RMB/m^3).

Attribute	INTERRUPT	PRESSURE	QUALITY	SERVICE
Mean WTP (95% CI)	0.18 (0.08–0.28)	0.88 (0.78–0.98)	2.33 (2.13–2.53)	0.23 (0.12–0.35)

The results begin with the quality attribute and indicate that respondents highly value water quality improvements. The MXL interaction model estimated an average WTP of 2.33 Yuan RMB/m^3 to improve drinking water quality. Generally, average residents are willing to increase 2.33 Yuan RMB/m^3 unit water price to ensure that drinking water quality could meet the standard all the time. Because water quality is the most significant factor among all attributes which actually influence individuals' personal health and might result in serious sicknesses, individuals are expected to pay more for improving water quality. In addition, water supply pressure was found as an important determinant of WSS behind water quality. From the model, respondents are willing to increase 0.88 Yuan RMB/m^3 unit water price to keep water supply pressure stable all the time. This suggests that currently, in Shenzhen, water pressure is not yet wholly stable and no water supply still happens in some districts. Thus, individuals would pay the second highest among all attributes for improving water pressure to prevent water outage. The results show that respondents have positive WTP for a better water supply service. They are willing to increase 0.23 Yuan RMB/m^3 unit water price to get more comprehensive water supply information and on-time maintenance services. This is consistent with the fact that individuals feel that less service needs to be provided regularly for water supply. Therefore, individuals prefer less for improving the service level in Shenzhen. Respondents value the improvement of water supply interruption the least. They are willing to increase 0.18 Yuan RMB/m^3 unit water price to reduce the frequency of water supply temporary interruptions. The reason for the low relative value of water supply interruptions is that water resource is relatively sufficient in Shenzhen. Most residents of Shenzhen are not under the pressure of water supply interruption.

The compensating surplus (CS) was estimated based on the MXL interaction model (presented in Table 6). To achieve the average WTP values and the 95% confidence intervals, Delta method was used. Five different scenarios are chosen to compared with status quo. The first four scenarios represent the improvement of one different attribute a time, and the last scenario is all attributes are improved. A best scenario is conducted, where all attributes would be improved. Based on the results, aggregate benefit for the best scenario is 3.63 Yuan RMB/m^3 (Scenario 5). Since each attribute was divided into two levels, the compensating surpluses of Scenarios 1–4 are numeric equivalent to the marginal value of each attribute, respectively. For example, Scenario 1 is based on reduced water supply interruption, unchanged water supply quality, pressure and service to the status quo. The average WTP for this improved scenario is 0.18 Yuan RMB/m^3. When the water supply safety is improved in Scenario 2, the average WTP increases to 0.88 Yuan RMB/m^3. In Scenario 3, the average WTP rises to 2.33 Yuan RMB/m^3. The mean WTP of Scenario 4 is 0.23 Yuan RMB/m^3.

Table 6. Compensating surplus for five possible scenarios (unit: RMB/m^3).

Attributes	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
INTERRUP	√	-	-	-	√
PRESSURE	-	√	-	-	√
QUALITY	-	-	√	-	√
SERVICE	-	-	-	√	√
	0.18 (0.16–0.28)	0.88 (0.76–0.92)	2.33 (2.30–2.66)	0.28 (0.22–0.38)	3.63 (3.02–4.25)

Note: "√" means improved, "-" means keep the status quo.

6. Discussions and Policy Implications

6.1. Consumers' WTP and Pricing Strategies

The results provide evidence that consumers are willing to pay significant additional unit water price for WSS improvement. The research also provides information of consumers' preferences for the characteristics of WSS improvement. Specifically, consumers are willing to increase 2.33 Yuan RMB/m^3, 0.88 Yuan RMB/m^3, 0.23 Yuan RMB/m^3 and 0.18 Yuan RMB/m^3 to improve water quality, water supply pressure, water supply service and water supply interruption, respectively (Figure 1). It is difficult to make a direct comparison about the WTP found in other studies not only because the attributes of the scenarios are different, but also because the context is different. However, to make a comparison between these findings in China and other recent survey results in other countries would be helpful. The study of Tarfasa and Brouwer [18] showed that households were willing to spend up to 80% more than their current water bill to improve water supply. In this study, Chinese residents were willing to pay almost double over the current water price. In the empirical analyses of Wang et al. [2], the results showed that Chinese water company's probability of "Upgrade" would be up to 80% by increase water price slowly (about 0.9–1.2 Yuan RMB/m^3). Meanwhile, the estimate results of this study demonstrate that consumers' WTP could almost match the water price adjustment for water companies and governments to improve water supply safety. Thus, reasonable water pricing is a necessary policy to improve WSS. In reality, Shenzhen is one of the first-tier cities in China. The level of per capital income in Shenzhen is higher than the levels in most other Chinese cities. From the analysis results above, "income" has a significant impact on consumers' choices on WSS improvement plan. More empirical studies are needed to compare WTP in different urban area with different levels of economic development.

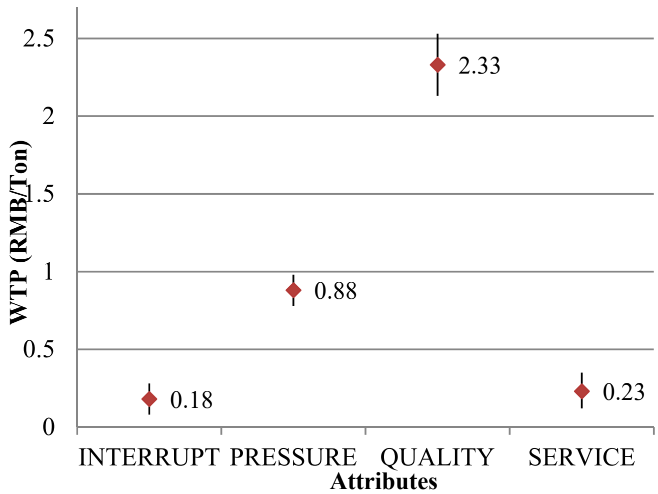

Figure 1. Consumers' willingness-to-pay for each attribute.

Since respondents were required to choose between attributes, they had to decide on which characteristics of the improvement program were the most significant for them. Attributes can be manipulated to reflect both future technological changes and policy-induced changes to invest in water industry. The results indicate consumers show a strong preference to improve drinking water quality. From consumers' demand, water supply pressure is also selected as an important factor in water supply safety. However, this important factor has been ignored for a long time in many developing countries. Unexpectedly, the WTP for decreased frequency of water supply interruption is lowest. This implied that the demand of improved water supply interruption is relatively low.

This information can be used by water companies for specific investment strategies and by governments for public policies. This finding advocates enhanced implementation of the new Standards for Drinking Water Quality (GB 5749-2006) which demands more strict rules and allocation of bigger budgets for drinking water quality improvement. It suggested water companies optimize their resource allocation and to make investment decisions according to consumers' preferences. It further suggested that higher welfare gains would be obtained if investments are prioritized towards improving water quality and pressure stability. Since Chinese consumers value in particular the quality of drinking water, priority should be given to the upgrade of the water treatment technology and facilities that implements additional measures to avoid water quality risk and protect human health. It is worth mentioning that water supply facilities largely determine the water quality that residents will finally receive. However, aging water supply facilities are the major challenge worldwide. In many cases, while the water quality is fine on discharge from a treatment plant, the water quality at the tap is invariably not. Thus, to improve water quality, reconstruction of water supply facilities should be invested in more initially. Water distribution networks may need to be better maintained or upgraded too. The investment strategies are shown in Table 7.

Table 7. Consumers' preferences to WSS and public policies.

Attributes/Factors	WTP/Impact	Public Policies
Improvement of water quality Improvement of pressure stability Improvement of water supply service Improvement of interruption	2.33 RMB/m^3 0.88 RMB/m^3 0.28 RMB/m^3 0.28 RMB/m^3	Priority in investment strategies to improve water treatment technology, facilities and distribution networks
Income Education level	+ −	Cross-subsidy policy
Concern about WSS Knowledge of WSS	+ +	Transparent Information and Communication Policy
Attitude to WSS improved projects Trust in the authorities	+ +	Public Participation Policy

Note: "+" means positive impact, "−" means negative impact.

6.2. Consumer Preferences and Incentive Polices

In this study, Chinese consumers' willingness to pay to improve WSS is influenced by gender, income and education. According to the analysis, female residents are more willing to pay to improve WSS than male residents. From the results discussed above, the group with higher income, higher education level and older people are more willing to pay because most of these individuals live in more developed sub-districts in Shenzhen. However, the group of individuals with higher income level but are older and less educated are willing to pay less, which implies they might live in less developed sub-districts in Shenzhen. Thus, price subsidy appears to be necessary and efficient. It calls for government's subsidy to those consumers to satisfy the basic needs of all people. However, instead of giving the subsidy directly from governments to those individuals lived in less developed sub-districts, the better way is to use cross-subsidy as a policy instrument. To not increase the financial burden of local governments, government could charge more on the water price for those individuals living in more developed sub-districts to subsidize for those individuals who live in less developed sub-districts to improve water supply safety.

The results reveal that respondents who express support in WSS improved project tend to increase water price to improve WSS. It is proven that consumers' concerns about WSS, trust in related authorities and information disclosure all have significant impact on the WTP. According to the significance of some factors such as information disclosure, it is suggested to motivate the drinking water market to disclose more information on all water supply processes. According to the importance of consumers' concern on WSS and information disclosure, public education and promotion about WSS are essential to get attention of consumers. Water supply stakeholders, including government authorities, experts, professional institution and water supply associations, would conduct lectures or campaigns to advertise WSS information, such as relevant standards and laws, main technology and processes. Water companies should release WSS information on time, such as their treatment and facilities. Since consumers' attitude to the WSS improved projects and confidence in the authorities are also significant with their WTP, it is crucial to encourage public participation in water supply management and policy decisions. Through public consultation, consumers would get better understand about WSS improved projects and management policies. The authorities and water companies would get better support from consumers. All suggested polices are presented in Table 7.

7. Conclusions

In summary, this study assessed consumers' preferences and willingness-to-pay for water supply safety using discrete choice experiment with cautious construction of choice sets, questions and data collection. This study clarified the value of water supply safety improvement in Shenzhen, China. The attributes of water supply safety improvement have been quantified so that they can be utilized for justification of WSS improvement programs in similar cities of China. The choice modeling provides WTP values of each attribute for WSS improvement in addition to the overall policy packages. The study highlights the importance of consumers' attitudes and perceptions for WSS across the choice sets.

It is concluded that consumers have positive willingness to pay to improve WSS. Regarding implicit prices and compensating surplus, consumers have the highest WTP (2.33 Yuan RMB/m^3) for improved WSS on water supply quality. Specifically, consumers are willing to increase water prices by 0.88 Yuan RMB/m^3, 0.23 Yuan RMB/m^3 and 0.18 Yuan RMB/m^3 to improve water supply pressure, water supply service and water supply interruption, respectively. By valuing WSS improvement attributes, policy makers can ensure the priority of the limited recourses in developing countries for sustainable management. It is recommended that higher welfare gains would be acquired if investments are prioritized towards improving water quality and pressure stability. It is proven that consumers' concerns on WSS, attitude to WSS improve projects, trust in related authorities and information disclosure have significant influence on their preferences to improve WSS. According to individuals' preferences, cross-subsidies should also be considered by the local government based on different developing level of sub-districts in order to improve water supply safety.

This study contributes to the recent literature not only by introducing attitudinal variables in choice experiment survey in water supply field, but also by representing the relevance of choice modeling applications in WSS improvement programs. Indeed, given the absence of overwhelming consumer demand, WSS improvement could not been accomplished without government incentives. However, whether governments and water companies can stimulate consumer demand to improve WSS and be further willing to bear more infrastructure upgrading cost, and, if so, how, is yet to be determined. Therefore, this paper further provides some insights into this issue too. Furthermore, there is a need for further research to compare benefits of WSS improvement with the actual cost. Since it was argued that heterogeneity would exist in consumer preference, consumer preferences heterogeneity for water supply safety requires investigations in future studies.

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