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Differentiated WTP for improvement of water quality in Miyun Reservoir, Beijing

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ABSTRACT

While scholars have studied extensively the individual determinants of willingness to pay (WTP) for improvement in environmental quality, few have delved into the nonparametric nature of such determinants. This study identifies the different major determinants for high and low WTP groups for improvement of water quality in Miyun Reservoir, Beijing. Using QR, interval regression, and Tobit model, this study finds that household income is highly and positively correlated with maximum WTP. In addition, attitude towards the environment, environmental knowledge, demand for improvement in environmental quality, education, and being male are all positively correlated with maximum WTP. In contrast, age is negatively correlated with maximum WTP, consistent with many existing studies. Compared with interval regression and Tobit, QR reveals more interesting results. We find that household income is more significantly correlated with WTP above the median maximum WTP value than below. For the top 1% of maximum WTP group, all nine determinants are highly significant, suggesting that the well-educated ones who command high salaries should be the target group of such policy initiative. By using QR, this paper sheds light on the varying public preferences rooted in income distribution and ability to pay in a fine-grained manner, and thus provides insight into effective policy targeting to implement water policies.

Keywords: Willingness to pay; Water quality; Quantile regression; Miyun Reservoir, China

1. Introduction

It is a truth universally acknowledged that water is essential for human existence and well-being across the world. Subpar provision of quality water can induce deteriorated health and social conflicts, making the nonmarket valuation of water quality ever more imperative to the governor and the governed alike. How much are the governed willing to pay for water quality improvement? Popular methodologies used for such purpose include contingent valuation (CV) and choice experiments (CE). CV is a non-market based direct valuation technique that asks survey respondents to value changes in the good in question, making trade-offs between environmental quality and other goods. CE presents survey respondents with a series of choice sets that represent different attribute bundles, allowing researchers to effectively isolate marginal attribute values and identify significant attributes. CE avoids some of the embedding and substitution problems of CV and proves effective at capturing individual attribute values of a project. While the results of both techniques are directly comparable, both make parametric assumptions about the nature of public preferences.

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However, studies have shown that these assumptions can be problematic because resulting WTP estimates can be sensitive to the selection of parametric specification [1].

To remedy the parametric specification problem, this paper employs quantile regression (QR) to single out the different determinants for WTP for water quality improvement in Miyun Reservoir, the main water source provider for the Beijing Metropolis, based on a survey experiment administered to a representative sample of Beijing residents. While previous study by Feng et al. [2] compared three valuation methods for water quality improvement in the Miyun Reservoir, we focus on public preferences, specifically willingness to pay, in this study. We find that income is highly and positively correlated with maximum WTP. In addition, attitude towards the environment, environmental knowledge, demand for improvement in environmental quality, education, and being male are all positively correlated with maximum WTP. In contrast, age is negatively correlated with maximum WTP, consistent with many existing studies [3–5]. Compared with interval regression and Tobit, which are traditionally popular, QR reveals more interesting results. We find that household income is more significantly correlated with WTP above the median maximum WTP value than below. For the top 1% of maximum WTP group, all nine determinants are highly significant, suggesting that the well-educated ones who command high salaries should be the target group of such policy initiative. Therefore, this study makes two methodological and practical contributions. Methodologically, our paper demonstrates that additional capabilities of QR over more traditional techniques in teasing out determinants for WTP for different WTP quantile groups. Practically, our paper offers new insights into the target groups for effective public policy design [6–8].

2. Literature review

CV and CE have long been used to assess environmental policies and conduct valuation analysis, especially for assigning values to environmental goods and services [1,33]. The assumption of conventional methods using CV data is that the determinants for the outcome variable are parametric, leaving the estimates sensitive to parametric specification. In addition, they estimate conditional mean functions. By contrast, the QR method [9] estimates a conditional quantile function, where a quantile of the response variable's conditional distribution is expressed as a function of covariates. Since QR allows its estimates to vary with the corresponding quantile, it is particularly useful when quantile effects exist, which is often quite true for data of public preferences. Other important advantages of QR include its superior capability in dealing with heteroscedasticity, outliers, and unobserved heterogeneity.

There has been a growing number of literature that use QR to assess the determinants of preferences or WTP. QR has been used to understand the factors that influence environment goods, such as cross-boundary water resource improvement [10], the effectiveness of energy conservation "nudges" [11], hydrogen buses [12], and the range of valuation of environmental goods [13]. In the realm of consumer goods, the QR method has been applied to study the pricing of hotels and houses [14,15], automobile pricing [16], legal purchases of digital music [17], willingness to accept compensation for consumer GM food in the United States and the EU [18], and the valuation of statistical life [19]. In the field of labor economics, QR has been applied to study race-based education returns to wage in South Africa [20], income inequality [21–25], income growth [26], and returns to self-employment [27]. Despite the aforementioned advantages of QR, there appear to be very few economic valuation studies using this technique to analyze the determinants of WTP along its distribution [28,29]. Therefore, this study adds to a thin pile of QR application in valuation studies, focusing on an important public policy issue of water quality improvement in one of the most populous metropolises in the world.

3. Research design

3.1. Study area

Miyun Reservoir, located in the northern mountainous region of suburban Beijing, is the capital city's major source of water supply (Fig. 1). With a capacity of 43.75 billion m^3, Miyun Reservoir is the largest water reservoir in northern China. The Reservoir gathers its water from 10 counties and county-level cities, of which 7 are located in Hebei Province and 3 in Beijing. To guarantee water quality and quantity, Beijing has negotiated with Hebei to offer ecosystem compensation fees to upstream farming households to grow upland rice, protect rivers, and plant trees.

3.2. Questionnaire design and data collection

CV questionnaires usually come in three types: open-ended, payment card, and dichotomous choice. Based on pre-survey testing, the authors found that payment card is the more intuitive way of indicating WTP among survey respondents in Beijing. It is also commonly used in developing countries where markets are less developed and residents are less familiar with market ideas [30]. This paper thus employs the payment card method in designing questionnaires.

To set the range of payment card, we used open-ended surveys during pre-survey testing to obtain the appropriate value range. In the survey prompt, we provide maps and descriptions to familiarize respondents with the upstream region and current ecosystem compensation policies. Maximum WTP is measured as the amount a household is willing to pay per month to support water quality improvement plans in the next 5–10 years.

The questionnaire collects the following information about the resident survey respondent. First, we ask about the respondents' knowledge and consciousness of environmental protection, including background knowledge of river protection, satisfaction with water provision services, trust of the government, and understanding of the potential damages of illnesses caused by water pollution and water quality deterioration. Second, we ask about their willingness and preferred means of payment, as well as the reasons why they will not want to pay. This is the core of the questionnaire, as it includes the degree to which the respondents support river protection and the maximum WTP to improve water quality in Miyun Reservoir. Third, we ask about their personal and household information, including the respondents'

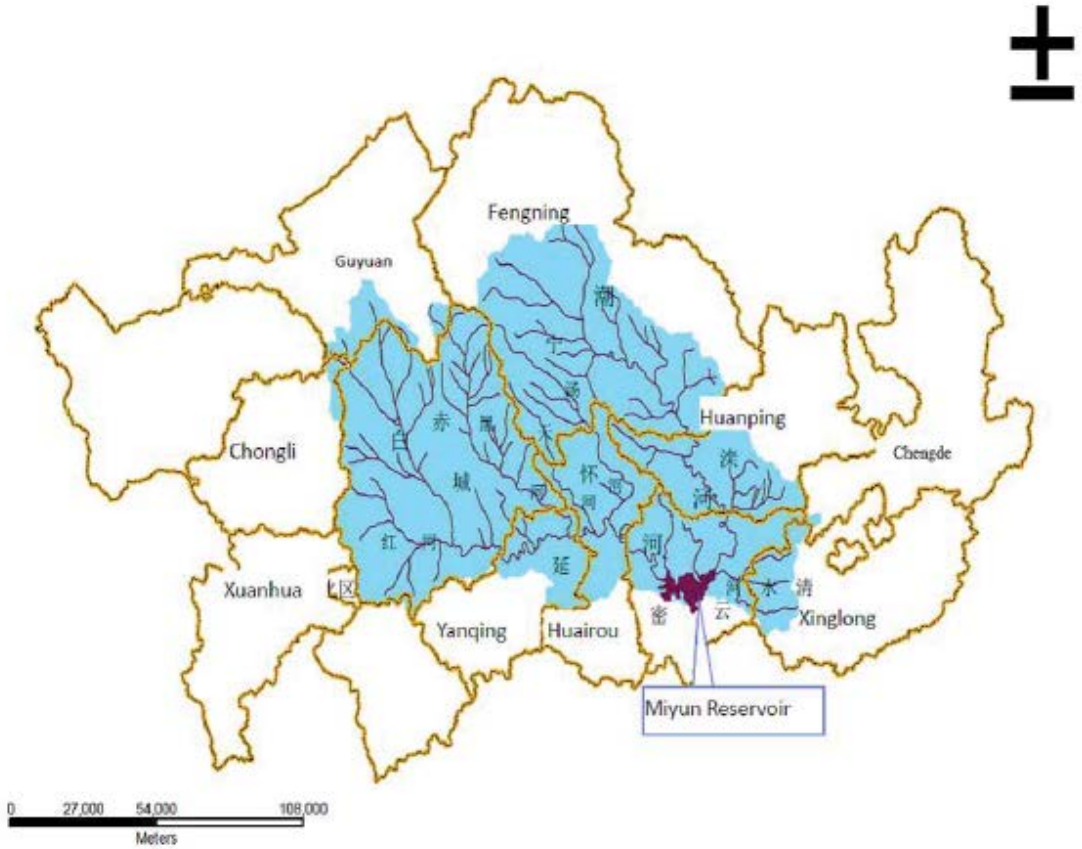

Fig. 1. Location of the Miyun Reservoir.

gender, age, years of education, household size, annual household income, and their area of residence. The core question of the survey is as follows:

In an effort to improve water quality and quantity of Beijing at the source, the municipal government of Beijing is currently gathering funding to establish a pilot project of river ecosystem compensation for the Miyun Reservoir. The fund will be used to pay upstream river protection and farming households whose activities will impact the water quality at Miyun Reservoir. This is critical to providing sufficient high-quality water to households in Beijing. Given this, how much are you willing to pay every month from your household income to support this initiative in the next 5–10 years?

☐5 ☐10 ☐15 ☐20 ☐25 ☐30 ☐35 ☐40 ☐45 ☐50 ☐55 ☐60 ☐65

☐70 ☐75 ☐80 ☐85 ☐90 ☐95 ☐100 ☐110 ☐120 ☐130 ☐140 ☐150

☐200 ☐250 ☐300 ☐350 ☐400 ☐500 ☐1,000

Survey respondents represent Haidian, Chaoyang, Fengtai, Shijingshan, Xicheng, Dongcheng, Xuanwu, Chongwen, and Changping districts. 370 surveys were conducted between March and June in 2010. Excluding surveys that were incomplete, 329 effective surveys were collected. Among these effective responses, 242 responses indicated willingness to pay. Among the 87 responses that indicated zero WTP, 14 were either unable to pay because their incomes were too low or because they believed that the polluter and the government should be responsible for defraying the costs of such initiative. The percentages of positive and negative WTP values represent 73.56% and 26.44% of the effective response pool.

3.3. Methodology

OLS, Tobit, logistic regressions are commonly used methodologies to measure the effectiveness of WTP assessment and the determinants of WTP. The shared premise of these regressions is that the determinants of WTP are parametric. However, in reality survey respondents belong to different groups that cannot always be characterized parametrically. In contrast, QR is able to tease out the significance and magnitude of various determinants for different WTP and income groups. Using QR can thus better capture the determinants of public preferences based on group characteristics and offer policy implications for river protection initiatives.

In order to test the effectiveness of QR in measuring WTP, this paper uses and compares among QR, Tobit, OLS, interval, and logistic regressions to assess how individual characteristics influence maximum WTP. Based on our initial results, we eliminated OLS and logistic models and kept QR, Tobit, and interval regression for maximum WTP analysis. Interval regression exploits the midpoint

between a respondent's WTP and the next WTP value for regression analysis. The payment card design of the questionnaire leads respondents to enter nonnegative WTP values, which allows for the application of a Tobit model for regression analysis. We describe model specifications in the following subsections.

3.3.1. Tobit model

Tobit model is quite commonly used to analyze WTP in payment card-questionnaires because such data is double-censored. In the Tobit model, the dependent variable y_i satisfies the following condition:

$$y_i = \max\left(0, y_i^*\right) \tag{1}$$

where y_i^* satisfies the linear assumption:

$$y_i^* = \beta_0 + \beta x_i + \varepsilon_i, \varepsilon_i \mid x - N\left(0, \sigma^2\right) \tag{2}$$

The independent variable x_i is observable while the outcome variable y_i (in this case, WTP) is restricted to a value range that is nonnegative.

3.3.2. Interval regression

Interval regression measures the probability of respondent *i*'s actual WTP, y_i, which can be represented by the interval [BIDL, BIDH]. Suppose that [BIDL, BIDH] can be estimated by [BIDL|*y*, BIDH|*y*], WTP-*N*(0,1). In our questionnaire, the midpoint can take on values of 5, 10, 15, 20, 25, 30, 35, 40, so on and so forth. If the respondent indicates a WTP of 5, the interval is [5,10]. If the respondent indicates a WTP of 17, the interval is [20,25]. Similar to OLS, Tobit, and logit models, interval regression model is estimated using maximum likelihood [8].

3.3.3. Quantile regression

Developed QR is capable of assessing the relationship between explanatory and outcome variables across the entire variable distribution, providing a more holistic assessment of the relationship. Compared with OLS and maximum likelihood, such as Tobit, logit, and interval regressions, QR estimates the conditional quantile functions where quantiles of the conditional distribution of the response variable (e.g., 0.1, 0.25, 0.5, 0.75, 0.9) are expressed as functions of observed covariates. QR is thus able to reveal differences in the significance and magnitude of determinants for the outcome among high and low interval groups. QR is thus a robust manifestation of even the outliers and skewed tails [31]. This feature makes it quite special in CV applications, since CV research often involves a small amount of very high WTP values and a large amount of very small WTP values. QR is thus an attractive method for the purpose of our research.

OLS, Tobit, logit, and interval regressions all make parametric assumptions about the explanatory variables. In the case of OLS, the coefficient of the explanatory variable indicates its average effect on WTP. However, none of this is enough to measure the true influence of such covariates on WTP. In this study, the QR model is as follows:

$$\mathrm{WTP}_i = X_i + u_i \tag{3}$$

$$\mathrm{Quantile}\left(\mathrm{WTP}_i \mid X_i\right) = X_i \tag{4}$$

3.4. Descriptive statistics

Table 1 exhibits description and descriptive statistics for the nine explanatory variables and the outcome variable. 71% of the respondents know that Miyun Reservoir is the main water source for Beijing. On a Likert scale of 1 (very unimportant) to 5 (very important) on the prominence of the environment vis-à-vis the economy, an average respondent thinks that the relative importance of the environment to the economy is somewhere between unimportant and very unimportant. 67% of respondents indicate that they purchase bottled water for its superior quality. 82% of respondents have demand for improvement in water quality. The median maximum WTP is 10 yuan/month-household, the mean 25.42 yuan/month-household (about 0.33% of household income), the minimum RMB 0 yuan/month-household, and the maximum 500 yuan/month-household. Detailed distribution of maximum WTP/month-household is shown in Table 2.

The discrepancy between high demand for water quality improvement and low levels of willingness to pay can be explained by many factors (Fig. 2). The top four given reasons for unwillingness to pay are as follows: the government should take the responsibility and pay for water quality improvement (32.43%); I cannot believe in the government or water resource agents for managing and using the funds well (29.73%); the polluter should pay (21.62%); and I am unable to pay due to very low household income (20.27%).

In terms of demographics, our sample is representative of the region in most respects except that it contains more young people and more female than the regional average. The age range for the survey respondents is 18–73 years old, where the average is 35.56 years. The average number of years of education is 14.7 years, the maximum 23 years (Ph.D.), and the minimum 2 years. 41% of the respondents are male. The minimum monthly household income is 1,000 yuan/month-household and the maximum 40,000 yuan/month-household.

4. Results and discussion

We use Stata 11.2 for regression analysis. The value range is restricted to 0–100 based on original data for the Tobit model. For interval regression, we calculated WTP at different intervals. As shown in Table 2, the intervals are defined by 5, 10, 30, 50 and 100 RMB/month-household. Table 3 shows the regression results for different regression models.

All three models suggest that average WTP is positively and significantly correlated with household income at the 99% significance level, which is consistent with multiple existing studies [32–36]. The interval regression and Tobit models also suggest that being male is significantly correlated with higher WTP, which may come as a surprise, given that a

Table 1
Definition and descriptive statistics of outcome and explanatory variables

Variable	Description	*N*	Mean	Standard deviation	Minimum	Maximum
WTP	Maximum willingness to pay	329	18.89	35.67	0	500
KNOWWAT (x_1)	Whether or not the respondent knows Miyun Reservoir is the major source of water provision for Beijing (1: yes; 0: otherwise)	326	0.71	0.46	0	1
ENVIMPT (x_2)	The relative importance of the environment to the economy (5: very important; 4: important; 3: neutral; 2: unimportant; 1: very unimportant)	325	1.59	0.79	1	5
BOTWAT (x_3)	Whether or not the respondent purchases bottled water for better-quality water (1: yes; 0: otherwise)	323	0.67	0.47	0	1
DEMWAT (x_4)	Whether or not the respondent has demand for improvement in water quality (1: yes; 0: otherwise)	326	0.82	0.38	0	1
GENDER (x_5)	1: male: 1 0: female	328	0.41	0.49	0	1
AGE (x_6)	Age of the respondent (≥18)	329	35.56	11.96	18	73
EDU (x_7)	Number of years of education the respondent has received	324	14.67	3.43	2	23
INCOME (x_8)	Monthly household income (RMB)	329	7,267.17	4,776.36	1,000	40,000
OCCUPATION (x_9)	Occupation of the respondent: 1: government; 2: NGO; 3: employees at privately-owned companies; 4: entrepreneurs; 5: workers, farmers, or service sector; 6: other, including unemployed and retired, student, and stay-at-home people	329				

Table 2
Distribution of WTP/month-household (RMB in 2010)

WTP (RMB)	Count	Percentage (%)	Cumulative percentage (%)
0	87	26.44	26.44
5	58	17.63	44.07
10	70	21.28	65.35
15	13	3.95	69.3
20	25	7.6	76.9
25	3	0.91	77.81
30	21	6.38	84.19
35	2	0.61	84.8
40	1	0.3	85.11
50	28	8.51	93.62
60	2	0.61	94.22
75	2	0.61	94.83
80	2	0.61	95.44
85	1	0.3	95.74
100	13	3.95	99.7
500	1	0.3	100
Total	**329**	**100**	

growing body of social science research link women to pro-environment attitudes [6]. In the interval regression model, WTP is positively correlated with education. In the Tobit model, WTP is positively influenced by the respondent's evaluation of the relative importance of the environment to that of the economy, but is negatively influenced by the age of the respondent, whether the respondent knows that Miyun Reservoir is the water source for Beijing, and whether the respondent purchases bottled water for better-quality drinking water. Counterintuitively, knowing that Miyun Reservoir is the major provider of water for Beijing has a negative effect on the respondents' WTP. It may be that respondents have been primed by news reports that Miyun Reservoir has been experiencing a shortage of water and water quality deterioration for almost a decade, so much as that payments at the individual level may not reverse such trend.

QR reveals more interesting results. Covariates that are insignificant in Tobit and interval regressions become significant for some quantiles in QR. For instance, the respondent's demand for water quality improvement is insignificant in both Tobit and interval regressions, but becomes significant at the 99% significance level for the 99th quantile. In addition, perceived relative importance of the environment to the economy, whether the respondent purchases bottled water, demand for water quality improvement, and age are all insignificant in interval regression, but they all become significant for the 99th quantile in QR. This shows that these covariates are not significant determinants for mean WTP, but are significant for the very high quantile. Significant covariates for the very high quantile can help provide policy reference.

Comparing among quantiles in the QR model, we can observe four principle findings. First, household income is significant at any quantile, and relative importance of the

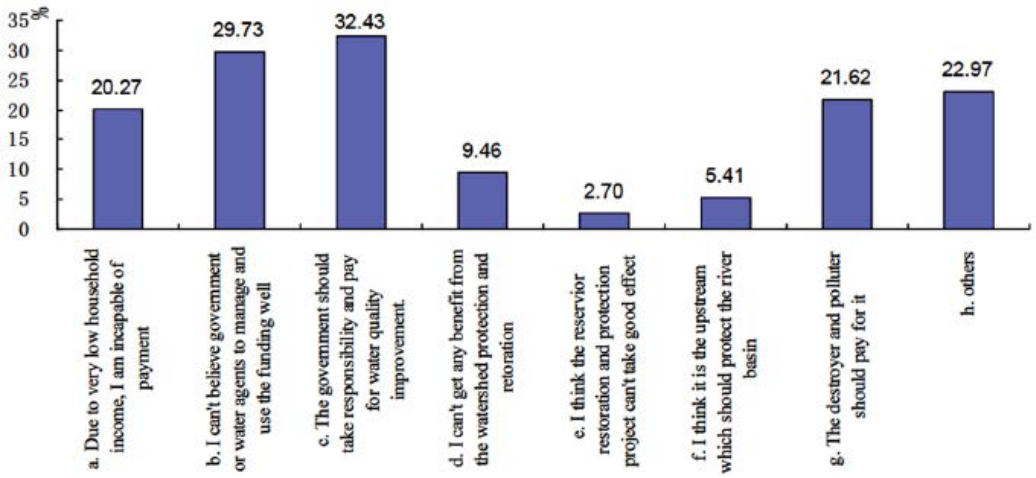

Fig. 2. Percentage distribution of reasons for unwillingness to pay for water quality improvement.

Table 3
Interval, Tobit, and quantile regression results for WTP improvement of water quality in the Miyun Reservoir

Variable	Interval	Tobit	OLS	QR_15	QR_20	QR_25	QR_50	QR_75	QR_90	QR_95	QR_99	BSQR_50
KNOWWAT	5.70	4.48	5.62	0.75	1.74	2.13	2.04*	3.36	17.74*	16.28	–7.71***	2.04
(x_1)	(5.93)	(3.80)	(6.01)	(1.21)	(1.04)	(1.17)	(2.74)	(6.76)	(8.72)	(115.61)	(0.45)	(2.27)
ENVIMPT (x_2)	5.54	8.07***	5.46	1.26	1.42*	2.03***	5.94***	12.53***	14.61**	10.83	–21.38***	5.94*
	(3.38)	(2.18)	(3.43)	(0.69)	(0.67)	(0.70)	(1.58)	(3.99)	(5.57)	(69.13)	(0.25)	(2.85)
BOTWAT (x_3)	–4.08	4.83	–4.17	0.96	1.07	1.32	0.32	1.18	9.13	18.98	–171.82***	0.32
	(5.81)	(3.73)	(5.90)	(1.29)	(1.10)	(1.20)	(2.66)	(6.51)	(8.36)	(148.45)	(0.43)	(2.50)
DEMAND (x_4)	5.58	1.61	5.50	–3.11	–3.04*	–3.56*	–0.70	3.51	–0.86	4.20	–32.87***	–0.70
	(8.20)	(5.25)	(8.32)	(1.93)	(1.46)	(1.64)	(3.74)	(9.06)	(11.92)	(89.88)	(0.60)	(3.46)
GENDER (x_5)	8.64	4.05	8.61	0.98	0.60	0.70	1.98	3.16	0.60	4.20	100.95***	1.98
	(5.17)	(3.32)	(5.25)	(1.19)	(0.98)	(1.07)	(2.40)	(5.95)	(8.66)	(146.96)	(0.39)	(2.40)
AGE (x_6)	–0.17	–0.27	–0.17	–0.01	–0.06	–0.08	–0.13	–0.39	–0.72**	–0.53	–0.83***	–0.13
	(0.23)	(0.15)	(0.24)	(0.05)	(0.04)	(0.05)	(0.11)	(0.26)	(0.29)	(4.15)	(0.02)	(0.10)
EDU (x_7)	1.21	0.18	1.20	0.20	0.21	0.24	0.32	0.28	0.11	0.78	5.83***	0.32
	(0.90)	(0.58)	(0.91)	(0.21)	(0.17)	(0.20)	(0.40)	(1.03)	(1.43)	(18.36)	(0.07)	(0.36)
Log	21.23***	15.68***	21.10***	3.02***	3.24***	3.74***	8.90***	21.21***	32.69***	26.81	106.02***	8.90***
(INCOME) (x_8)	(4.86)	(3.12)	(4.93)	(0.90)	(0.86)	(0.89)	(2.20)	(6.01)	(7.20)	(97.83)	(0.36)	(2.49)
OCCUPATION	1.08	–0.88	1.09	–0.23	0.03	–0.02	0.14	–0.83	–2.23	–2.06	6.73***	0.14
(x_9)	(1.92)	(1.23)	(1.95)	(0.47)	(0.38)	(0.41)	(0.89)	(2.30)	(3.39)	(45.17)	(0.14)	(0.95)
Log likelihood				0.11								
LR chi2(9)				14.44								

*, **, ***: significant at 1%, 5% and 10% probability levels, respectively.

environment to the economy becomes significant at the 25th quantile and above. Second, determinants for WTP differ between low quantile and high quantile groups. Besides household income, for low-quantile groups only relative importance of the environment to the economy (at the 25th quantile) and demand for water quality improvement (at the 10th quantile) are significant. More covariates become significant above the median WTP. This is mainly due to low-quantile WTP being a smaller portion of household income, which is consistent with existent studies [35,36]. Third, the sign of some determinants change for different quantile groups. For instance, whether the respondent knows that Miyun Reservoir is the main water source for Beijing and whether s/he purchases bottled water are negatively correlated with WTP in Tobit analysis, but both become positively correlated with WTP for the 99th WTP quantile group. This intuitively makes sense and shows that QR reveals more important insights than Tobit or interval regression. Last but not least, all covariates have significant effects on WTP for the right-hand tail of WTP. Besides age, which has a negative effect on

WTP, all other covariates are positively correlated with WTP. It shows that WTP in questionnaires based on prompt statements is driven by various factors for different WTP quantile groups. In the case of public preferences in water quality, it demonstrates that different groups have qualitatively different determinants for their public preferences.

As has been shown, QR has an obvious edge over Tobit and interval regression models in value analysis of payment card data. By analyzing the determinants of WTP for high-quantile WTP groups, QR model provides policymakers with better information on effective targeting in order to garner more public support (i.e., higher WTP). If the implementation plan is tailored for an average resident in the sample, then its implementation will not be very effective for the low-quantile WTP group [37]. Conversely, if implementation plan is designed separately for different quantile groups, residents with differing levels of WTP, the policy will likely solicit more public support and higher WTP from each quantile group. The same strategy will also apply to other environmental policies. Future research can delve into the goodness of fit of QR models for large-n dataset, especially that with a significant amount of outliers. In addition, future research can experiment with using QR to model and analyze WTP data.

5. Conclusion and policy implications

This paper uses interval regression, Tobit, and QR to determine public preferences – manifested by WTP – for improvement of water quality. The major finding, as demonstrated by all three models, is that average WTP is significantly influenced by household income, meaning that the higher income a household commands the higher the demand for improvement in water quality. QR model shows that relative importance of the environment to the economy becomes significant at the 25th WTP quantile and above, suggesting that the rating of the importance of the environment is also critical for WTP and that the government should enhance public education of the importance of water protection and safety in order to garner more public support.

The QR model shows that the determinants are different for high- and low-quantile WTP groups. For low-quantile WTP groups, only the relative importance of the environment and demand for water quality improvement are significant, besides household income. These three determinants become more significant above the median. For the top 1% of WTP group, all nine determinants are highly significant, suggesting that the well-educated ones who command high salaries should be the target group of such policy initiative. In addition to its policy implication, our findings illustrate the usefulness of QR methods for analyzing CV data, as they enhance our understanding of the determinants of WTP for an indispensable environmental good.

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