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ORIGINAL ARTICLE

Estimating residents' willingness to pay for groundwater protection in the Vietnamese Mekong Delta

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Abstract Groundwater in the Vietnamese Mekong Delta is facing the pollution and it needs to be protected. Searching literature reviews on economic valuation techniques, the contingent valuation method (CVM) has been popularly applied to estimate the economic value of water protection. This approach is based on a hypothetical scenario in which respondents are requested through questionnaires to reveal their maximum willingness to pay (WTP) for the water protection project. The study used the approach of CVM to analyze the households' motivations and their WTP for the program of groundwater protection in the Mekong Delta. The study performed that the residents in the delta were willing to pay approximately 141,730 VND (US$6.74) per household a year. Groundwater could be an inferior good with the negative income effect found in the demanding for clean groundwater. Respondent's gender and groundwater-related health risk consideration were factors sensitively affecting the probability of demanding for groundwater protection.

Keywords Contingent valuation · Groundwater pollution · Probit model · Sensitivity analysis

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Introduction

The Mekong Delta (MD) is facing the pollution of the groundwater resource. The pollution sources are contamination by agriculture activities, surface pollutants by incompetent drilling wells, natural phenomenon as arsenic pollution, and salinity due to over-extraction. In the modern input-based agriculture economy, water resources are seriously degraded. Along with rivers and canals, groundwater aquifer is being polluted. The contamination by agriculture production is a consequence of overusing pesticides, fertilizers, and other chemical materials. These pollutants infiltrate into groundwater through incompetent tube wells that are found in many places in the MD. It is said that in the MD more than 15 % of private dug wells cannot be used because of improperly drilling.

The fact that arsenic pollution in groundwater has just been observed at many places in the MD raises more concern about the health risks for its residents. Long An, Dong Thap, An Giang, and Kien Giang are provinces having very high possibility of arsenic pollution in groundwater. It is said that arsenic is a culprit for skin cancer to human. Preventing the source of pollution and using other alternative water sources become the main concern in these days. In addition, salinity of groundwater caused by over-extracting is another story of groundwater pollution in the MD. The variance of water table between the rainy season and the dry season tends to increase year to year. At some places, people cannot use groundwater because of the salinity; although in the past, it is easy to get the groundwater for domestic uses. Managing groundwater production is considered as a measure to protect this invaluable natural resource.

Groundwater needs to be protected. Policy chosen should be recommended based on responses of the

consumers who are directly affected by the quality of groundwater. Households' perception on groundwater-related issues decides their behavior to the potential markets through the price or the willingness to pay (WTP) to prevent the pollution that they cope with the health risks. The potential or contingent markets for public good like groundwater are policies proposed to prevent the pollution. Economically, WTP estimate is to measure the monetary amount that the household is willing to pay to avoid the losses from pollution. In other words, an economic valuation of groundwater protection measures the social welfare to be maintained if the pollution problem can be avoided.

For environmental goods like a groundwater protection service, pricing its value differs from the private goods. Some methods of economic valuation are developed and applied in the real world. Many studies are implemented in the developed countries while few of them are conducted in the developing countries. There are basically two approaches for economic valuation, namely, the stated preference and revealed preference method. The contingent valuation method (CVM) is one of the most popular tools among the valuation techniques of stated preference method. In developing countries, the application of CVM for water-related goods has been popularly implemented in recent years. Choe et al. (1996) used CVM technique with three question forms of referendum, follow-up yes/no, and open-ended to estimate the economic value that the people in Davao of the Philippines placed on improving the water quality of the rivers and sea near their community. Results suggested that water pollution control was not high priority for the residents and supported the argument that households' WTP for environmental amenities such as improved water quality was low. Whittington et al. (2002) used CVM technique with yes/no question to estimate households' demand for improved water services in Kathmandu, Nepal, where the government considered the possibility of involving the private sector in the operation of municipal water supply services. The results provided the first evidence from South East that households' WTP for improved water services was much higher than their current water bills.

In Vietnam, Phuong and Gopalakrishnan (2003) used the CVM technique to estimate the loss of value of water resources due to pesticide contamination in the Mekong Delta of Vietnam. Results showed that the economic losses were about US$251 million. Nam and Son (2005) applied the CVM technique with single-bounded dichotomous choice question to derive households' WTP for improved water services in Ho Chi Minh City, Vietnam. The payment vehicle was households' monthly water bill. The results showed that the WTP amount for improved water services was higher than the sum of their existing water bills plus coping costs like collecting, pumping, treating, storing, or purchasing water. Khai (2014) applied the CVM to estimate the Mekong Delta urban households' WTP of VND 267,550 (US$12.67) per household, nearly equal to 1.41 % of the average annual income of households in the study area, for the surface water improvement project. However, those of studies in Vietnam have nothing related to the benefit of groundwater protection. This paper is an attempt to estimate household preferences for groundwater protection using the approach of CVM. A contingent market contains several elements which are required to elicit theoretically valid measures of WTP during a household survey (Mitchell and Carson 1989). A respondent is introduced to a hypothesized market presenting a proposed Groundwater Protection Program (GPP) and a WTP value is then asked for voting to contribute into GPP fund. This study might provide policy makers and concerned people more information about residents' attitudes toward groundwater as well as the environmental problems in Vietnam.

The paper is structured as follows. The next section describes the methodology and data collection. The following section reports the results and discussion of WTP for groundwater protection, including the estimation and sensitivity analysis of WTP value. The final section presents some conclusions and policy implications of the study.

Methodology

The approach of CVM, favored by many environmental economists (e.g., McFadden 1973; Hanemann 1984; Sun et al. 1992), is based on the utility difference framework to estimate the WTP for an environmental good like groundwater protection. Supposing that an individual with household income (Y) derives a Hicksian private good (X) with the price of P_x and a public good groundwater (W) with the price of P_w, the maximization problem is presented as follows:

$$\begin{aligned} U &= U(X, W) \\ \text{s.t.} \quad & P_x X + P_w W = Y \end{aligned} \tag{1}$$

Solving the Eq. (1) will yield the indirect utility function $V(.)$:

$$V = V(P_x, P_w, Y) \tag{2}$$

Assuming that CVM survey presents a household maximum WTP to maintain a provision of groundwater at the present level (Q^0) from a future worse level (Q^1) if groundwater is not protected from pollution, the model of household's WTP for protecting groundwater quality is presented as follows:[1]

[1] Q^0 and Q^1 are eliminated assuming that the groundwater quantity is the same under with or without the GPP. In this case only price of groundwater is changed. That is why we denote P_H and P_L for P_w.

$$V(Y, P_x, P_L|S) = V(Y - WTP, P_x, P_H|S) \quad (3)$$

where S is the vector of household characteristics, P_L is the current low price of groundwater, and P_H is the higher price of groundwater if it is contaminated in the future.

The Eq. (3) shows that the WTP is the decrease in income which makes an individual indifferent between protecting and not protecting groundwater quality. WTP is also explained as the compensating variation measure of a change in welfare. It is a measure of the total economic value that a household pays to protect groundwater from pollution. Protecting groundwater quality brings some benefits for the groundwater users. These benefits include use values such as avoiding health risks, reducing higher water costs due to treatment cost or other water purchases as well as non-use or passive values. Thus, when a person pays a WTP to purchase groundwater quality by protecting groundwater from pollution, he or she is purchasing a set of environmental services.

Following Sun et al. (1992), the effects of supply and demand uncertainties are introduced into the Eq. (3). Let δ a person's subjective estimation of contamination probability in a case of without the GPP. With the GPP, δ is assumed to be zero. Let γ a person's subjective estimation of future demand. As a result, a model for economic valuation of groundwater quality protection incorporated into subjective estimation of groundwater supply and demand represents as follows[2]:

$$\begin{aligned}&\gamma V(Y - \text{WTP}, P_x, P_L|S) + (1-\gamma)V(Y - \text{WTP}, P_x|S)\\ &= \delta V(Y, P_x, P_H|S) + (1-\delta)V(Y, P_x, P_L|S)\end{aligned} \quad (4)$$

The dichotomous choice approach with the format of closed-ended question is used to estimate the WTP (Edwards 1988; Schultz and Luloff 1989; Sun et al. 1992; Caudill and Hoehn 1992; Poe 1993; Clemons et al. 1995; Whittington et al. 2002; Nam and Son 2005). Carson et al. (1999) argued that "the closed-ended format is incentive compatible when a survey is perceived by respondents as a potential source of influence on policy decision-making". A respondent is asked whether or not he or she would be willing to pay an offer price of X VND to have groundwater quality assured by the GPP. Theoretically, a respondent will accept the price if his/her utility does not decline under the Program.

$$\begin{aligned}&\gamma V(Y - X, P_x, P_L|S) + (1-\gamma)V(Y - X, P_x|S) + e_1\\ &= \delta V(Y, P_x, P_H|S) + (1-\delta)V(Y, P_x, P_L|S) + e_0\end{aligned} \quad (5)$$

where e_1 and e_0 are random variables with zero means. From the Eq. (5), the probability of a "yes" response to the WTP question is written as follows:

$$\begin{aligned}\Pr(\text{Yes}) = \Pr\{&\gamma V(Y - X, P_x, P_L|S) + (1-\gamma)V(Y - X, P_x|S) + e_1 \geq\\ &\delta V(Y, P_x, P_H|S) + (1-\delta)V(Y, P_x, P_L|S) + e_0\}\end{aligned} \quad (6)$$

If η is defined as $\eta = e_1 - e_0$, then

$$\begin{aligned}dV = &[\gamma V(Y - X, P_x, P_L|S) + (1-\gamma)V(Y - X, P_x|S)]\\ &-[\delta V(Y, P_x, P_H|S) + (1-\delta)V(Y, P_x, P_L|S)] + \eta \geq 0\end{aligned} \quad (7)$$

In a reduced form, the Model (7) can be described as a function:[3]

$$dV = K(\gamma, \delta, X, Y, P_H, P_L, S) \quad (8)$$

If $F_\eta(.)$ is the cumulative distribution function for the random variable η, then $\Pr(\text{Yes}) = F_\eta(dV)$. Thus, the dichotomous choice approach can be interpreted as the outcome of the utility-maximizing choice (Hanemann 1984). In the study, the Probit model with assumption of $F_\eta(.)$ that is the cumulative density function (cdf) of the respondent's true maximum WTP is used as followings:

$$\Pr(\text{Yes}) = [1 + \exp(-dV)]^{-1} \quad (9)$$

$$\text{Or} \quad \Pr(\text{Yes}) = [1 + \exp(-K(\gamma, \delta, X, Y, P_H, P_L, S))]^{-1} \quad (10)$$

Using the linear utility model for the Probit model in (10), the WTP is calculated as follows:

$$X = \left(-\sum_{j=1}^{n} \alpha_j Z_j\right) \Big/ \beta \quad (11)$$

where X is the option price or the WTP; β is the option price coefficient; Z_j are the means of other independent variables described in the Eq. (10); and α_j are the estimated coefficients associated with Z_j.

Research design

Before designing the questionnaire, the focus group discussion was conducted to get the information sufficient to the CVM situation in the study site. Based on the preliminary questionnaire, a pretest with a small sample was done. The CVM surveys generated data sets about the responses on household characteristics, attitudes, and opinions and WTP responses (Bateman 2002). In this study, CVM survey was used to elicit a household's WTP to eliminate the potential future groundwater contamination

[2] the absence of P_L in $V(Y - \text{WTP}, Q^0, P_x|S)$ shows that groundwater is not consumed.

[3] As the utility difference in the Model (7) is solved, P_X drops out of the equation.

from pollution. The survey questionnaire contained a hypothetical referendum designed to measure a household's WTP for the GPP which would help protecting groundwater from pollution. The CVM survey consisted of three parts.

The first part described knowledge and perception of a respondent about environmental issues and groundwater resource as well and a hypothesized market scenario used to elicit a household's WTP. In describing hypothesized market, the potential future groundwater contamination by types of pollution such as agricultural chemical, possibility of natural pollutants iron and arsenic was discussed. Then the GPP was introduced to invite people to build the fund for preventing or eliminating the pollution or at least maintaining the currently "safe" groundwater quality by installing the treatment equipment to remove the toxic in groundwater (see "Appendix 1" presenting the description of CVM Scenario 1). To test whether respondent's answers to the WTP questions were sensitive to the "scope" of the environmental service groundwater protection, a second method of removing toxic in groundwater was using chemical treatment instead of treatment equipment (Scenario 2). Thus, a split sample was used to test for the "scope" or "embedding" effects of the CVM survey (Boyle et al. 1994; Carson et al. 1994).

The second part consisted of questions that elicit the WTP for the groundwater protection. The valuation process was designed to minimize the selection bias on the WTP answers. Respondents were asked to vote for the GPP given the amount of income reduction (e.g., offer price). For those who voted for the GPP, to get additional information, open-ended question of the maximum WTP was asked. For those who did not vote for the GPP, the follow-up questions about the reasons why a respondent do not vote for the program were asked to identify protest bid respondents (see "Appendix 1" for more detail). Moreover, to examine whether the WTP referendum was consistent with the respondent's concern about the GPP, questions on the opinion of voter for the GPP were designed in this section.

The third part included questions on the households' demographic such as age, sex, income, and so on. The information in this section was treated as exogenous variables and used in regression equations to estimate a valuation function for the groundwater protection service. Additionally, the subjective evaluation of the household on groundwater supply and demand was also asked in this section.

Study location and data collection

The study was conducted in Soc Trang province, one of MD regions where groundwater users are the most crowded. It has an area of 3,223 km^2 and a population of approximately 1,213,400. There is 77 % of the population living in the rural areas. About 64 % of Soc Trang population enables to assess the clean water for domestic use in which groundwater is an important source. Like other areas in the MD, the agricultural production in the province is characterized by heavy using of fertilizers, pesticides, and other bio-chemical agents. In recent years, it is reported that there is a clear evidence of existing of nitrates and other pollutants from agriculture. It is high possibility that the groundwater contamination would happen if groundwater is not protected.

In the study, the economic valuation problem for groundwater protection from pollution is defined as the measurement of benefits of protecting currently "safe" groundwater from the potential future contamination. The questionnaire was firstly applied in a small pilot survey to give more statistics information served for the decision on selecting a suitable sample size.[4] The formal survey was implemented in five districts of Soc Trang Province; they are Thanh Tri, Nga Nam, My Xuyen, My Tu, and Soc Trang Town. The questionnaire was asked using face-to-face interview technique. Five hundred and ninety-eight households were randomly selected by the cluster sampling technique for the first CVM scenario in which groundwater was hypothetically treated using water filtering equipment.

Some ways could be applied to solve the problem of zero bids in the contingent valuation literature. Imber et al. (1991) treat all "no" responses as real "no" answers. This may result in wrong policy implications (Carson 1991) or difficultly estimate the WTP function correctly if the number of protest responses is high (Romer 1992). Other strategy is to eliminate all zero bids, but this may cause a sample selection bias since the remaining bids no longer originate from a random sample of the basic population (Romer 1992). The most common way is to identify and exclude protest bids from estimates of WTP (Mitchell and Carson 1989). Cummings et al. (1986) stated that if a person bids zero as a protest to being asked to pay for an environmental good, the bid is not an indicator of his true valuation. Protest bids are inconsistent with an implicit model of contingent valuation behavior. Following suggestions by Khai and Yabe (2014) and other previous CVM studies to discriminate between valid and protest zero bids, respondents who are not willing to pay any positive bids with the reasons "I do not think protection of groundwater from pollution is worth doing" and "I do not believe that the money that I will pay will actually be used for the Groundwater Protection Program" are considered as the group of protest bids. As a result, a sample of 574 households was selected in the study after these protest bids are

[4] Sample size determined to the official survey follows the formula $SE_{WTP} = \sigma/n^{1/2.}$

screened out of the sample. Additionally, a split sample of 88 households was randomly selected with the same sampling technique for the second CVM scenario in which groundwater was hypothetically treated using chemical technique. Both samples were divided into eight subgroups. Each of these subgroups received one of eight offer prices assigned for the referendum question. The offer prices were 50,000 VND, 75,000 VND, 100,000 VND, 125,000 VND, 150,000 VND, 175,000 VND, 200,000 VND, and 250,000 VND, respectively. These values are equivalent to bid values in US dollars[5] of $2.37, $3.55, $4.74, $5.92, $7.11, $8.29, $9.47, and $11.84. These offer prices were based on the focus group discussion and the results of pretest survey.

Table 1 shows the sample structure and the proportion of respondents who voted for the offer price referendum question. The first approach used the answers from the initial referendum question only with either "yes" or "no" answer to the proposed price. The study shows that most of the people are willing to pay for the GPP within the next 5 years with the fact that the voting rate is very high ranged from 63 to 78 % of sample population. There is a trend that for all groups of households, as the proposed price increasing, the percentage of respondents supporting the GPP generally decreasing. To model the determinants of WTP responses to the initial referendum question, an individual is assumed to compare his or her current utility level to the utility level that would be obtained under the GPP program described in Scenario 1 and the amount of paying per year within next 5 years.

Table 2 shows the mean statistics of socio-economic or demographic variables and other variables used for analysis. The sample population has an average age of 42 in which 57 % of respondents were greater than 40 years old. Sample households with the average income of about VND 2 million VND per month have about 7.4 years going to school, 49 % are male respondents, 48 % are farmers, and 75 % live in the rural areas.

Households selected in the sample are those who are using groundwater from private tube wells and Groundwater Supply Units (GSUs) managed by the state and private companies at the proportion of 54 and 46 %, respectively. In evaluating the subjective probability of supply and demand for the groundwater in the future, 48 % of respondents asked whether the groundwater in the area is polluted in the next 5 years answered "yes". There are 10.6 % of households planning to move another place in the next 5 years. Moreover, the effect of groundwater pollution to human health is concerned by 88.4 % of sample population.

[5] 1 USD = 21,110 VND at the date of 26/09/2013.

Table 1 Sample structure and percentage of respondents voting for the offer price

Offer price (VND)	Sample mechanism in offer prices (%)	Scenario 2: chemical use ($n = 88$) (%)	Scenario 1: use filtering equipment ($n = 574$)		
			Tube well user (%)	GSU user (%)	Total (%)
50,000	12.4	80	79	76	78
75,000	12.2	78	88	70	78
100,000	12.9	92	81	84	84
125,000	11.9	36	68	89	75
150,000	12.8	83	73	61	66
175,000	12.7	64	70	78	73
200,000	12.7	64	74	59	70
250,000	12.4	55	67	60	63

Results and discussion

In estimating the WTP, variables affecting the responses of the households play an important role. Despite the difficulties in interpreting the analysis of WTP data of endogenous variables (Bateman 2002), along with exogenous variables, they were used to form the WTP model. Exogenous variables are those over which the household has no choice and endogenous variables are those whose values are determined through choices made by the household.

In this study, two kinds of variables jointly used to determine the WTP responses of the household. Socio-economic and demographic variables are defined as exogenous variables and groundwater situation and opinion and attitude variables are defined as endogenous variables. The signs expected for coefficients are also presented in Table 2. The coefficients of *Income* (Household income), *Educ* (education status), *Famsz* (family size), *Depn* (number of children), and *Demand* (demand probability for clean groundwater) variables are expected to be positive while those of *Supply* (supply probability for clean groundwater) and *Hecon* (respondent's concern about health impact of using groundwater) variables are expected to have negative signs in the Probit model. Moreover, households in the rural area (*Locatn*) and respondent's subjective evaluation on current groundwater quality (*Wqual*) are variables expected to have negative signs while respondent's concern about groundwater pollution (*Poconn*) and respondent's rating on the environmental issues (*Enval*) positively affect the WTP responses.

The WTP responses of respondents associated with Scenario 1 are used to estimate households' WTP for protecting groundwater from pollution. There were two kinds of WTP estimation depending on the different

Table 2 Descriptive statistics of variable in the analysis

Variable	Description	Scenario 1	Scenario 2	Expected signs
Income	Income[a] (VND/month)	1,972,855 (1,151,909)	2,363,636 (1,598,719)	+
Age	Respondent's age (number of years)	42.39 (13.501)	42.70 (12.465)	?
Genr	Respondent's gender dummy[b] (1 for male; otherwise 0)	0.48 (0.613)	0.55 (0.501)	?
Educ	Respondent's education (number of years)	7.34 (3.659)	7.60 (3.716)	+
Ethnic	Respondent's ethnic dummy[b] (1 for majority; otherwise 0)	0.58 (0.495)	0.38 (0.487)	?
Career	Respondent's career dummy[b] (1 for farmer; otherwise 0)	0.47 (0.500)	0.53 (0.502)	–
Locatn	Respondent's location dummy[b] (1 for rural; otherwise 0)	0.74 (0.439)	0.82 (0.39)	–
Famsz	Family size (number of persons)	5.07 (2.069)	4.93 (1.818)	+
Depn	Number of children (number of persons)	0.79 (0.958)	0.81 (0.993)	+
Groundwater situation				
Ustype	Type of user dummy[b] (1 for private tube well; otherwise 0)	0.54 (0.499)	0.44 (0.500)	?
Demand	Demand probability[c]	0.88 (0.323)	0.97 (0.183)	+
Supply	Supply probability[d]	0.53 (0.499)	0.35 (0.480)	–
Opinions and attitudes				
Poconn	Respondent's concern about groundwater pollution dummy[b] (1 for having concern; otherwise 0)	0.53 (0.500)	0.52 (0.502)	+
Wqual	Respondent's evaluation on groundwater quality (1 for extremely good, 5 for very bad)	2.94 (0.913)	3.20 (0.697)	–
Enval	Respondent's evaluation on the environment issue dummy[b] (1 for seriously bad; otherwise 0)	0.16 (0.370)	0.20 (0.406)	+
Hecon	Respondent's concern about health impact of using groundwater (1 for extremely concerned, 5 for not concerned at all)	2.37 (0.960)	2.60 (0.891)	–

Numbers in parentheses are standard deviations

[a] Income is evaluated at mid-point

[b] Mean estimates of dummy variables should be interpreted as percentage

[c] Estimated subjective probability of clean groundwater demand within 5 years. It is calculated by the formula (1-*Move*), where *Move* is the probability of moving out of the village

[d] Estimated subjective probability of clean groundwater supply in 5 years. It is followed by the assumption of the possibility of groundwater contamination evaluated by the respondent

formats of CVM question asked to elicit the WTP of the respondent. For the dichotomous choice question with the analysis based on binary data, the Probit model was used to explain the initial votes for and against the program. For the open-ended question with the analysis based on continuous data, the WTP mean and median were estimated using survival analysis. The results of the analyses from Probit and ordinary least squares (OLS) models are presented in Table 3.

In Table 3, the Probit model shows that the higher the monthly price offers to the respondents, the less likely they are to vote for the GPP. It is consistent with the behavior of the household followed by rule of demand. All of estimators, excepting *Income*, have signs as expected. Surprisingly, the household income has a negative relationship with the voting for the GPP. The lower the household income, the more likely the respondent was to support the GPP. This can be explained as follows. If it is not difficult to get clean water from the tube well or is easy to buy from the GSU, it is a normal good. In this context, the relationship between the household income and the demand for clean water (by voting for the GPP) is positive. Conversely, if the possibility of assessing the clean groundwater is at the edge of the risk, for instance, due to contamination, it could be an inferior good. In this case, as the prediction of demand theory, the demand for groundwater protection decreases as household income increases. Possible explanation could be that respondents with high income who prefer clean water (tap water) to groundwater consider groundwater as an inferior good. The results also show that respondent's gender and education status are exogenous variables, which are statistically significant determinants of household response to the referendum question. The probability of residents' accepting the suggested price by a male head is higher than female while their accepting rate increases for those who have higher education.

Besides exogenous variables being determinants of WTP response in the Probit model, four endogenous variables (*Demand*, *Poconn*, *Enval*, and *Hecon)* are positively

Table 3 Analysis of households' willingness to pay for groundwater protection

Variable	Probit model[a]		OLS model[b]	
	Coefficient	*P* value	Coefficient	*P* value
Constant	1.3660	0.000	−55,437	0.223
Price	−3E−06	0.007	0.5751	0.000
Income	−3E−08	0.096	0.0089	0.069
Age	−0.0038	0.507	966.63	0.044
Genr	0.4889	0.001	8,215	0.350
Educ	0.0236	0.084	4,358	0.017
Ethic	−0.03156	0.826	8,977	0.472
Career	−0.0169	0.907	−23,551	0.059
Locatn	−0.2470	0.100	16,582	0.101
Famsz	−0.0026	0.945	−3,984	0.213
Depn	−0.0484	0.554	−5,476	0.418
Ustype	0.0511	0.714	25,048	0.030
Demand	0.2409	0.088	9,913	0.560
Supply	−0.0909	0.535	−3,014	0.807
Poconn	0.1178	0.092	9,393	0.414
Wqual	0.0233	0.771	952.90	0.884
Enval	0.2409	0.100	1,878	0.906
Hecon	−0.3906	0.000	−3,847	0.585
Log(*L*)	−226			
χ^2	58.08			
(Pseudo) R^2	0.1137		0.1806	
Mean WTP (VND)	141,730		122,838	
95 % WTP confidence interval (VND)	153,667–140,190		111, 429–134,247	

[a] Dependent variable is dummy equal to one if the answer is "yes" to vote the initial price

[b] Dependent variable is the maximum price that a respondent votes in open-ended question

related to and statistically significant determinants of household responses to the referendum questions. These suggest an increase in the probability of accepting the suggested price for residents who have higher demand possibility (proxy variable of not moving out of the area within next 5 years), give care to the pollution of groundwater, evaluate the environment state currently very bad, and concern the health impact of using groundwater.

Results in the OLS model show that the initially proposed price positively affects the maximum price that a respondent is willing to pay for the program. An increase of 10,000 VND in the initial price on the maximum price is 5,751 VND. The results also show that only exogenous variables presenting social-economic and demographic characteristics of household affect the maximum price that a respondent votes for the GPP. These statistically significant variables are *Income* (household income), *Age* (respondent's age), *Edu* (respondent's education status), and *Career* (respondent's career). Among respondents who demand for groundwater protection, as a monthly household income increases 100,000 VND, each resident is willing to contribute 890 VND more for the groundwater protection project. If the age or education of sample resident increases 1 year, he or she can pay the maximum price of about 1,000 VND or 4,360 VND, respectively. Education status plays an important role in perception on groundwater pollution problem—a respondent faced. A respondent who is a farmer would pay for the GPP less than those who are not a farmer at 23,550 VND.

The estimated coefficients of the statistically significant variables in the Probit model presented in Table 3 are used to calculate the Hicksian welfare benefits from the GPP to protect groundwater from pollution by applying the Eq. (11). The economic benefit of protecting groundwater measured by the mean WTP value is determined at 141,730 VND per year per household. At the 95 % confidence interval, the mean WTP value ranged from 153,667 VND to 140,190 VND.[6] The WTP value using the information from the open-ended question is calculated about 122,838 VND per year per household by the survival analysis technique with the 95 % confident interval between 111, 429 VND and 134,247 VND per year. The mean WTP value estimated by the first approach (i.e., single referendum choice question) is relatively higher than the mean WTP value estimated by the second approach (i.e., open-ended question) at the edge of 15.4 %.

A separated set of analysis is also conducted to test whether CVM scenario affects household's WTP response. Results are presented in Table 4. All of signs of coefficients for statistically significant variables are consistent with signs of coefficients of the same variables in Table 3. This split-sample experiment designed to test for "scope" or "embedding" effects shows that respondent's answers are not sensitive to variations in the commodity described in the hypothesized markets. The coefficient of *Scenario2* dummy variable indicates that the scope effect does not happen in the Probit model. In other words, household's WTP response is not dependent of the commodity described in the hypothesized markets. One possible explanation of this result is that a single referendum question simply provides less information on a respondent's values than other referendum question formats; so, the Probit model cannot as readily discriminate between those who received the two scenarios (Hanemann et al. 1991). However, in the OLS model, the result shows that respondents are sensitive to the scope of the commodity described in the scenarios. Those who are introduced with the chemical materials to filter paid less than 27,591 VND as those who are introduced with the filtering equipment. The highest amount of money

[6] Since the negative effect of household income, the lower bound and upper bound values had an opposite direction.

Table 4 Models testing the significance of the scope of CVM scenarios

Variable	Probit model[a]		OLS model[b]	
	Coefficient	*P* value	Coefficient	*P* value
Constant	1.1778	0.000	−40,438	0.331
Price	−3E−06	0.003	0.5660	0.000
Income	2E−08	0.106	0.0094	0.021
Age	−0.0071	0.104	884.30	0.051
Genr	0.4533	0.001	7,983	0.324
Educ	0.0173	0.083	3,564	0.027
Ethic	−0.0491	0.712	6,728	0.549
Career	0.0634	0.633	−20,907	0.063
Locatn	−0.1917	0.104	10,474	0.183
Famsz	0.0040	0.909	−4,282	0.107
Depn	−0.0722	0.322	−135.53	0.982
Ustype	0.0617	0.626	22,226	0.030
Demand	0.1560	0.068	12,586	0.434
Supply	−0.0883	0.518	−5,982	0.594
Poconn	0.1467	0.096	7,843	0.448
Wqual	0.0198	0.793	76.87	0.990
Enval	0.0739	0.122	4,480	0.749
Hecon	−0.3499	0.000	−2,926	0.642
Scenario2	−0.0272	0.883	−27,591	0.080
Log(*L*)	−268			
χ^2	59.41			
(Pseudo) R^2	0.0999		0.1781	

[a] Dependent variable is dummy equal to one if the answer is "yes" to vote the initial price

[b] Dependent variable is the maximum price that a respondent votes in open-ended question

paid by the former is less than 23.2 % of the amount paid by the later.

To take into account the uncertainty in estimating the mean WTP value, a sensitivity analysis is done with the base case of 141,730 VND mean WTP estimated by the Probit model. For the continuous variable of household income (*Income*) and the interval variables respondent's education level (*Educ*) and concern on health risk (*Hecon*), these values used to estimate new mean WTP values are one standard deviation below and above the mean value while the dummy variables of respondent's gender (*Genr*), location (*Locatn*), demand probability (*Demand*), concern on groundwater pollution (*Poconn*), and environmental issue evaluation (*Enval*) used to estimate new mean WTP values are zero and one. Results of sensitivity analysis are presented in Table 5.

Table 5 shows that the mean WTP values are very sensitive to a respondent's gender, concern on health risk as using groundwater, and subjective evaluation on the environmental issue. The male head of household has his

Table 5 Sensitivity analysis of the WTP responses

Variable	Value	Option price (VND)[a]
Income	798,225[b]	153,676
	3,251,851[c]	128,724
Genr	0 (min)	62,181
	1 (max)	227,910
Educ	3.705[b]	112,651
	11.035[c]	171,291
Locatn	0 (min)	203,690
	1 (max)	119,961
Demand	0 (min)	213,593
	1 (max)	131,932
Poconn	0 (min)	120,567
	1 (max)	160,499
Enval	0 (min)	73,136
	1 (max)	154,797
Hecon	1.395[b]	270,828
	3.315[c]	16,607

[a] The estimated option price uses means of the variables having a mean of 141,730 VND

[b] The value is one standard deviation below the mean value

[c] The value is one standard deviation above the mean value

WTP of 227,910 VND per year, while a female respondent is willing to pay only 62,181 VND per year for groundwater protection. The interval difference is at 3.5 times. Next, those who take care of more on health risk of using groundwater are willing to pay much more for the GPP fund at the bid price of 270,828 VND per year to expect to obtain an unpolluted groundwater source. The difference depending on a respondent's attitude to health impact is 16.3 times. Finally, a respondent's perception on environmental issues affects the WTP response choice. Those who think that the environment quality is seriously bad exercise higher price than those who do not care about it. The offer price of the former is willing to pay was 154,797 VND per year while the latter is willing to pay was only 73,136 VND per year.

Conclusions

This study tried to estimate household preferences for groundwater protection using the approach of CVM. Results of the Probit model analysis showed that the economic benefit of protecting groundwater was 141,730 VND per year per household. There was no "scope" effect affecting the WTP response of a respondent in the study. It means that a respondent's WTP response was not dependent of the type of commodity described in the contingent market. His or her participation in the GPP program was of

concerning the pollution for groundwater source possibly affecting the clean water use and not because of the type of commodity supplied in the hypothesized market. Results of survival analysis performed that the mean WTP value was 122,838 VND per year per household. The mean WTP value estimated by Probit model was relatively higher than the mean WTP value estimated by the survival analysis.

The study also indicated that groundwater would be an inferior good with the evidence of negative relationship between household income and the demand for groundwater protection. This means that clean water (tap water) is the necessary good for people in the MD. Besides household income, respondent's gender and education status were significantly exogenous variables affecting the WTP response. Additionally, there were four endogenous variables positively related to household responses to the referendum questions, namely, subjective demand, respondent's concern about groundwater pollution, respondent's evaluation on the environment issue, and respondent's concern about health impact of using groundwater.

The OLS model showed that initially proposed price positively affects the maximum price that a respondent was willing to pay for the GPP program. This indicated that the estimated WTP using survival analysis method could be affected by the starting point chosen to elicit the monetary amount for voting the GPP. Only exogenous variables presenting social-economic and demographic characteristics of household affected the respondent votes for the GPP. These statistically significant variables are household income, respondent's age, respondent's education status, and respondent's career.

Although the study was made to estimate the economic value of groundwater protection from pollution, it should not be used as the sole basis for evaluating the groundwater protection projects. There are two important limitations of using such economic efficiency criterion, namely, the ethical legitimacy of using households' existing preferences for groundwater projection projects and distributional effects of not protecting groundwater from pollution. Taking into account the two limitations, the contribution of the study is to provide important, policy-relevant information for evaluating groundwater protection projects and water sanitation investments as well. Public awareness of groundwater pollution status, environmental degradation and protection, and the effects of environmental issues to health risk are likely to have a dramatic effect on rational behaviors or wide residents' support for environmental improvement. Perception of the public plays an important role for the acceptance of public investment projects. This study is a pioneer in research type toward public participatory-based projects.

Conflict of interest The authors declare that there is no conflict of interests regarding the publication of this article.

Appendix 1: Description of CVM scenario and referendum question format

At Soc Trang Province, groundwater is a main source of drinking and cooking water for residents in the rural areas during the dry season when river is salinized and polluted. Results from previous studies of wells at Soc Trang Province showed that groundwater wells contain nitrates. Nitrates are chemical substances hazardous to human health if they are taken in large quantities. Most of the wells in the survey in 1999 implemented by Center of Water Resource Evaluation had nitrate levels below hazardous levels.

To cope with the problem of groundwater pollution, the government establishes an action plan the so-called Groundwater Protection Program which mobilizes the fund and uses the money from the fund to buy an equipment to remove the nitrates and other polluters from groundwater at private wells and public wells. Suppose that you are invited to contribute to the fund.

After reading the above statement, the respondents will be asked if they receive their water from their own wells or from a public well. If they check "own well", they are asked to read the following statement:

Suppose that you found that the amount of nitrates in your well water exceeds the safe level. Suppose also that to protect the people from illness, due to the usage of polluted groundwater, a local authority (through a public water supply company) offers to install and maintain new equipment on your well. This equipment will clean your water from nitrates, but the water supply company will charge you for the use of its equipment. If you do not want to pay to the water supply company, the equipment will not be installed and you have to bear the risk of increasing nitrates in your drinking water.

If the respondents receive public water, they will be asked to read the following statement:

Imagine that the amount of nitrates in underground water will increase. This will increase the costs of cleaning water. Imagine that the local water supply company will make sure that your water is safe for drinking but will increase your monthly water bill.

Given this assumption, please evaluate and give YOUR BEST ANSWERS to questions Q.11 to Q.14.

Q. 11 Would you vote to support the Groundwater Protection Program for preventing groundwater pollution from agricultural pesticides, fertilizers, and other polluters, if the program reduces the amount of money you have to spend on other goods and services by _____VND?

Yes ☐	No ☐	Do not know ☐	Q11

If Do not know, proceed to Q.12; if No, proceed to Q.13, and if Yes, skip to Q.14.

Q.12 Understandably there are various factors that you are considering before you can decide whether to agree or oppose the Groundwater Protection Program. What are the reasons that hinder you from making your decision at that time?

Q12

.....

.....

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.....

Q.13 What are the reasons why you did not vote for the program?

a. I cannot afford that amount	☐	Q13a
b. I do not think protection of groundwater from pollution is worth doing.	☐	Q13b
c. I do not believe that the money that I will pay will actually be used for the Groundwater Protection Program.	☐	Q13c
d. I think other environmental issues are more important than pollution of groundwater.	☐	Q13d
e. Others (please verify)		

Q.14 What is the HIGHEST amount the program could reduce the amount of money you have to spend on other goods and services BEFORE you would vote against it?

.....VND	Q14

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