

# Evaluating the welfare effects of improved water quality using the choice experiment method

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## **Abstract**

This paper analyzes the welfare effects of improved health status through increased water quality using a choice experiment. The survey was administered to a random sample of households in metropolitan Cairo, Egypt. We apply a random parameter logit model in the analysis and illustrate the richness of information that can be obtained from this type of model by estimating individual level willingness to pay (WTP). We find a significant WTP for improved health status, both for short-run and long-run health effects. However, the estimated WTP is fairly low compared with the costs of a program that would achieve these improvements.

*Keywords:* Choice experiment; Health; Water quality; Willingness to pay.

*JEL classification:* C25; I10; Q25

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## **1. Introduction**

The Earth is now home to more than 6 billion people. Out of this population, 1.1 billion lacked safe water and 2.4 billion lacked adequate sanitation in 2000 (World Bank, 2000). As a consequence, water and sanitation-related diseases are widespread. Nearly 250 million cases are reported every year, with more than 3 million deaths annually. Diarrheal diseases impact children most severely, killing more than 2 million young children a year in the developing world. Many more are left underweight, stunted mentally and physically, vulnerable to other deadly diseases, and too debilitated to go to school. In Egypt, the World Health Organization (2002) reports the under age five mortality to be 46 per 1000 live births in 2001, and 20 percent of all child deaths every year are due to diarrheal diseases. The total volume of water required to meet basic needs ( $15 \text{ m}^3/\text{year}$ ) is relatively small compared to agricultural and industrial uses. Accordingly, the problem of household consumption is not water quantity but rather quality. The availability of safe drinking water, combined with sanitary facilities and improved hygiene standards, could prevent many diseases.

The purpose of this study is to estimate the benefits of water quality improvement programs related to health in metropolitan Cairo. This is important in order to compare these benefits to the cost of water management programs and for policy makers to design tariffs. The paper focuses on the magnitude and socioeconomic determinants of the willingness to pay (WTP) to improve health through enhanced water quality. Previous applications involve the estimation of household demand for improved water services (e.g. Whittington et al., 1988, 1990, and 2002a) and studies done in the health area such as Alberini et al. (1997) and Whittington et al. (1996, 2002b) using the contingent valuation method (CV). In this study a further step is taken by applying the choice experiment (CE) technique to estimate the welfare effects of improved water quality. Both CV and CE are hypothetical approaches that in many respects are similar. However, with CE it is possible to obtain richer information about people's preferences, although this at the same time means a more complex choice situation for the respondents. For an overview of choice experiments see e.g. Alpizar et al. (2003) or Louviere et al. (2000). The CV method has been shown to work quite satisfactorily in developing countries (Whittington, 1998), but there are very few studies using the CE method in developing countries, and to the authors' knowledge this is the first applied in this field. The choice experiment

exercise typically requires the presentation of information to the respondent about the terms and conditions of the program offered. This is quite a complex task *per se*. In a developing country where illiteracy is quite prevalent, the task is even more challenging. It is therefore of particular interest to study how choice experiments can be applied in this context.

The rest of the paper is organized in the following way. In Section 2 the choice experiment is described. In Section 3 the econometric model, a random parameter logit model, is presented. The results are presented in Section 4 and Section 5 concludes the paper.

## **2. The Choice Experiment**

The final questionnaire was preceded by a number of focus group discussions and a major pilot study. The questionnaire contained a number of sections, other than the choice experiment, including questions about the socio-economic characteristics of the household and questions about the water quality and health status of the household. Focus groups and pre-testing with a sample of individuals were used to determine some measurable attributes associated with the effect of the quality of drinking water on health. These attributes were: (1) Short run health effect. This was described as the number of ill days caused by waterborne diseases during the year, e.g. diarrhea. This attribute was related to the current level of the household's health status, so the actual levels varied among the households (2) Long run health effect. This was related to the risk of contracting a dangerous disease in the future. A bundle of diseases such as hepatitis and cholera were mentioned in the scenario. (3) The cost attribute was formulated as an increase in the water bill due to the program. Two different sets of prices were prepared and offered according to the current water bill, which is paid every two months by most households. Those with water bills less than 20 Egyptian pounds (L.E.) were offered a lower set of prices than households with higher bills.<sup>1</sup> Eight price levels were used, based on the distribution results from an open-ended CVM pilot study.

The attributes, as well as the levels, are described in Table 1. Given this set of attributes and levels, a linear D-optimal design method was used to structure paired choice sets; see e.g. Kuhfeld (2001) and Carlsson and Martinsson (2003) for

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<sup>1</sup> 1 USD = 4.5 L.E. in September, 2002.

overviews of experimental design. The set of attributes and levels presented in Table 1, was used to create paired choice sets using an  $(4^3 \times 4^3)$  orthogonal main effects design, which produced 24 choice sets. To these paired choices a *status quo* alternative was added in all sets. The sets were then blocked into six versions of four choice sets each, using a D-optimal criterion. Focus group work showed that respondents could cope with up to four choice triplets each. In the survey, each household was randomly assigned to one version.<sup>2</sup>

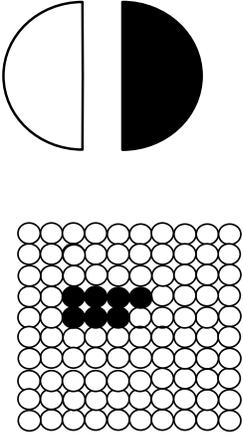
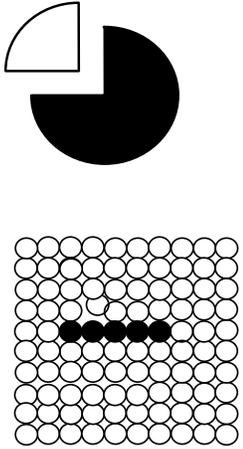
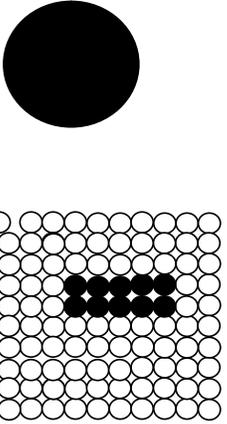
**Table 1:** Attributes and levels of the choice experiment

<i>Attribute</i>	<i>Levels</i>
Short run health effect: number of ill days	Same as today 5% decrease 25% decrease 50% decrease
Long run health effect	10% risk of contracting a disease 7% risk of contracting a disease 5% risk of contracting a disease 2% risk of contracting a disease
Price (increase in water bill)	0, 2.5, 10, 20 L.E. or 0, 5, 20, 40 L.E.

The scenario began with a brief text describing the proposed health program. The interviewer first read the text aloud and then asked the respondent to describe how the program would affect the household health. After eliciting perceived impacts, the choice experiment portion of the question detailed the resulting outcomes (services to be obtained) from the program. Respondents were asked if they had any questions regarding the project. The interviewer then gave a brief list of reasons for making different choices in the experiment in order to remind the respondents of the health trade-offs and the budget constraints involved in a voting decision. An example of one of the choice sets is presented in Figure 1.

<sup>2</sup> The six sets were offered in the form of different questionnaires. Each questionnaire was randomly assigned to a sample ranging from 124 to 130 households.

**Figure 1:** Example of one of the four choice sets in the choice experiment task

Option A	Option B	Status quo
 <p data-bbox="477 821 516 846">7%</p>	 <p data-bbox="808 821 847 846">5%</p>	 <p data-bbox="1122 821 1177 846">10%</p>
2.5 L.E.	20 L.E.	No increase in the bill

Due to the illiteracy of the respondents it is almost necessary to use visual aids. According to the World Bank Indicators, in 2001 the illiteracy rates of Egyptian females and males were 55 and 33 percent, respectively. Hence, the use of visual material was applied in order to facilitate the task of the respondents to understand the trade-offs that must be made when making a choice. A number of risk communication tools have been developed in the literature to assist respondents in comprehending the magnitude of risk reduction. For instance, Corso et al. (2001) show not just the importance of visual aids in conveying risk, but also that the type of visual aid matters as well. They test the effects of visual aids on WTP responses and find that communicating risk using an array of dots enhances the sensitivity of the estimated WTP to the magnitude of risk reduction, yielding CV estimates that are more consistent with economic theory. Loomis and duVair (1993) have also tested the effect of different visual aids on WTP. Based on this evidence, together with the use of focus groups and pilot testing, we chose to describe the short run health effect by means of pie charts where the black circles indicate the number of ill days per year. The offered improvement was illustrated by the white part of the pie chart. The long run risk was represented by the aid of an array of dots, where black dots indicated the risk of contracting a disease.

### 3. Econometric model

The standard approach in the analysis of choice experiment responses is the random utility model, where it is assumed that the utility function consists of both a systematic and a stochastic part. The utility function for household  $h$  of alternative  $i$  in choice set  $t$  is therefore written as

$$U_{hit} = V_{hit}(X_{it}, Z_h, y_h - c_{it}) + \varepsilon_{hit}, \quad (1)$$

where  $X_{it}$  is the attribute vector (including alternative-specific constants),  $Z_h$  is a vector of socio-economic characteristics,  $y_h$  is income,  $c_{it}$  is the cost associated with the alternative and  $\varepsilon_{hit}$  is an error term. We apply a random parameter logit model in this paper. Compared with the standard multinomial logit that has been applied frequently in the past, the advantages are the explicit modeling of unobserved heterogeneity and that the model does not exhibit the independence of irrelevant alternatives property; see for example Train (2003). We assume that the deterministic part of the utility function is

$$V_{hit} = \beta X_{it} + \gamma Z_h + \delta(y_h - c_{it}). \quad (2)$$

The vector of coefficients  $\beta$  varies among the population with  $f(\beta | \theta)$ , where  $\theta$  is a vector of the true parameters of the taste distribution. If the error terms are independently identically distributed type-I extreme value we have a random parameter logit, or mixed logit, model (Train, 2003). The conditional probability of alternative  $i$  for household  $h$  in choice situation  $t$  is then

$$L_h(it | \beta) = \frac{\exp(\beta X_{it} + \gamma Z_h - \delta c_{it})}{\sum_{j \in \mathbf{A}_t} \exp(\beta X_{jt} + \gamma Z_h - \delta c_{jt})}, \quad (3)$$

where  $\mathbf{A}_t = \{A_1, \dots, A_N\}$  is the choice set. The conditional probability of observing a sequence of choices, denoted  $y_h$ , from the choice sets is the product of the conditional probabilities:

$$P(y_h | \beta) = \prod_t L_h(y_{ht} | \beta). \quad (4)$$

In the choice experiment, the sequence of choices is the number of hypothetical choices each respondent makes in the survey. The unconditional probability for a sequence of choices for individual  $h$  is then the integral of the conditional probability in equation (4) over all values of  $\beta$ :

$$P(y_h | \theta) = \int P(y_h | \beta) f(\beta | \theta) d\beta. \quad (5)$$

In this simple form, the utility coefficients vary among individuals, but are constant among the choice situations for each individual. This reflects an underlying assumption of stable preference structures for all individuals (Train, 1999). Since the integral in equation (5) cannot be evaluated analytically, we have to rely on simulation methods for the estimation of probabilities. Here we will use a simulated maximum likelihood estimator using Halton draws to estimate the models; see Train (2003). Without a loss of generality, we assume that attribute parameters and the alternative-specific constant are normally distributed, which means that we estimate a mean and a standard deviation for each of the normally distributed parameters. One interesting aspect of RPL models that has been explored only recently is the possibility of retrieving individual-level parameters from the estimated model using the Bayes Theorem. This means that we can obtain the distribution of a specific parameter for a specific group of respondents. The intuitive explanation for this is that a person's choices reveal his or her preferences. In the same way we can talk about the distribution of the random parameters for the group of individuals that we observe making the sequence of choices  $y_h$ . The mean  $\beta$  for this group of respondents is in turn (Train, 2003):

$$E[\beta_h] = \frac{\int \beta P(y_h | \beta) f(\beta | \theta) d\beta}{\int P(y_h | \beta) f(\beta | \theta) d\beta}. \quad (6)$$

This expression does not have a close form either, so a simulation method would have to be applied here as well.

## 4. Results

### 4.1 Descriptive results

In January of 2002, an in-person survey concerning waterborne illness and the value of clean water was administered to about 750 households in metropolitan Cairo. In order to meet a target of 750 households, a random sample of 840 was drawn to allow for non-responses. Metropolitan Cairo was defined as the urban districts of the Cairo, Giza and Kalyubia governorates lying within the ring-road. The study used a random sample weighted by population drawn from the sample design of the 2000 Egyptian Demographic and Health Survey, which is based on a three-stage probability

sample. For details on the sample design, see El-Zanaty and Way (2001). Respondents were split as evenly as possible between male and female heads of the households in order to allow for testing of gender related differences in responses. Table 2 reports the descriptive statistics of the socio-economic characteristics of the interviewed households.

**Table 2:** Description of the sample and variables used in the analysis.

Variable	Description	Mean	Std.	Min	Max
Income	Household income, equivalence scaled (Egyptian pounds/month) <sup>a</sup>	286.7	443.92	17.4	8000
High Education	= 1 if head of household completed secondary school or higher	0.28	0.45	0	1
Medium education	= 1 if head of household finished primary schooling or continued to secondary school	0.25	0.43	0	1
Low education	= 1 if head of household has some primary schooling	0.19	0.39	0	1
No education	= 1 if head of household has no education	0.28	0.45	0	1
Employed	= 1 if head of household is employed	0.73	0.44	0	1
Female head	= 1 if the household head is a female	0.14	0.35	0	1
Child	= 1 if at least one of the household members is under the age of five	0.31	0.46	0	1
Not bad health	= 1 if self-assessed health status of the household is not bad	0.22	0.42	0	1
Diarrhea	= 1 if a member of the household contracted diarrhea during the past year	0.41	0.49	0	1
Water cost	The household's payment for water consumption LE/month	6.79	6.48	0	99
<i>Status quo</i>	= 1 if the household always chose the opt out	0.40	0.49	0	1
Cost	Increase in water bill	6.94	8.34	0	40
Short run health effect	Decrease in the number of ill days (in percentage reduction)	14.69	18.97	0	50
Long run health effect	The risk of contracting a disease (in percent)	2.75	3.14	0	8

<sup>a</sup> The weights used are 1 and 0.7 for an adult and an under 15 year olds household member, respectively.

Forty percent of the sample chose the *status quo* in the four offered choice sets, while 38 percent never chose the *status quo*. After the choice experiment, respondents were asked to motivate their responses. Around 26 percent of the participants supported the positive short run effects of better water quality, while 51 percent of the respondents believed in the reduction of long run ill health effects by enhancing the water quality. Since better water quality may lead to better health, around 26 percent of the respondents were willing to contribute to the program.

**Table 3:** Reasons for the choices made by the respondents.

Reason	Share
Reduce short run problems	25.46
Reduce the probability of diseases in the long run	50.79
Better health worth the cost (instead of going to the doctor)	26.12
No short run problems	4.62
Don't believe in long run effects	1.72
Can't pay more expenses	40.5
Waterworks can't provide the service	1.98

#### 4.2 The Random Parameter Logit Model

Table 4 presents the results for the random parameter logit model. The estimated mean and the standard deviation are reported for each random parameter. The model is estimated with simulated maximum likelihood using Halton draws with 250 replications. We have used Limdep Nlogit 3.0 in all the estimations. Since the short run attribute is based on a base case of a number of ill days, this variable is interacted with the variable indicating whether they have contracted diarrhea in the last year. The reason is that we expect only this group of respondents to have a positive WTP for a reduction in the number of ill days.

**Table 4:** Estimation results of the choice experiment.

Variables	Coeff	P-value
<b>Fixed parameters</b>		
Income	2.4547	0.004
High Education	4.5431	0.000
Medium education	3.3567	0.000
Low education	3.1930	0.000
Employed	0.6773	0.337
Not bad health	-1.2790	0.075
Child	0.8510	0.205
Female head	-1.5481	0.073
Cost	-0.1009	0.000
<b>Random parameters</b>		
Alternative specific constant (not choosing opt-out)	-5.0203	0.000
Short run health effect	-0.0011	0.709
for households that have		
{ not contracted diarrhea in the past year	0.0069	0.039
{ contracted diarrhea in the past year	0.3305	0.000
Long run health effect		
<b>Standard deviation of random parameters</b>		
Alternative specific constant (not choosing opt-out)	6.1928	0.000
Short run health effect	0.0017	0.873
for households that have		
{ not contracted diarrhea in the past year	0.0088	0.555
{ contracted diarrhea in the past year	0.3134	0.000
Long run health effect		
Number of respondents		757
Number of choice sets		3028
Pseudo R <sup>2</sup>		0.38

Most of the socio-economic characteristics that interact with the alternative-specific constant are significant. Households with higher incomes, as well as household heads with higher levels of education are more prompted to choose an alternative that is not the *status quo*. Perhaps surprisingly, the presence of a child below the age of five does not have any significant effect on the choices. Note that the alternative-specific constant is negative indicating that, all else equal, respondents have a preference for the opt-out alternative. All the attributes in the choice experiment are significant and have the expected sign. The only exception is the group of respondents that have not contracted diarrhea in the last year. This group does not, as we expected, care about improvements in the short run health, because in the experiment this is defined from the current state and since this is good already they do not focus on this attribute in the experiment. The estimated standard deviations for the random parameters for the long run health effect attribute and for the alternative specific constant are significant indicating an unobserved heterogeneity.

#### 4.3 Welfare Analysis

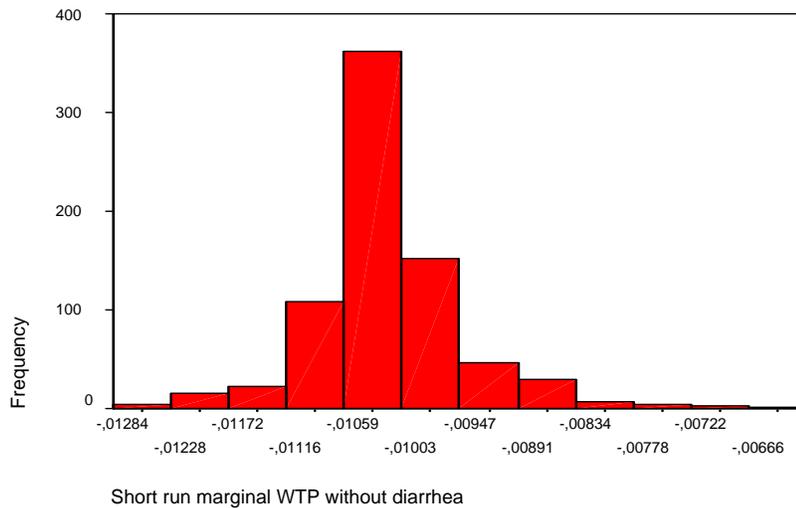
A number of welfare measures can be obtained from the estimated model. Here we report the marginal WTP for each attribute and the WTP for a certain proposed change in the attributes. The marginal WTP for a certain attribute is, given our assumptions about a linear income effect, the ratio of the attribute coefficient and the marginal utility of income (Hanemann, 1984), where the coefficient for the cost attribute is interpreted as the marginal utility of money. Table 5 presents the marginal WTPs for the attributes. The standard errors are calculated with the Krinsky-Robb method using 1,000 replications (Krinsky and Robb, 1986).

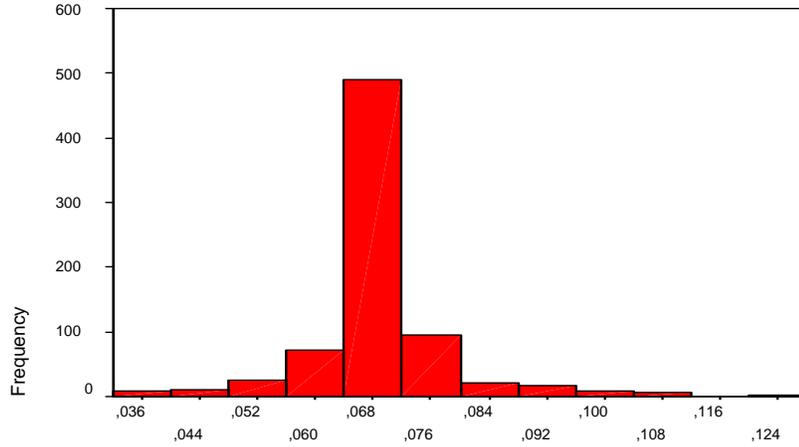
**Table 5:** Mean marginal WTP in Egyptian pounds, 95% confidence intervals in parentheses.

	Mean marginal WTP	Probability reversed sign	Share with reverse sign, using individual-level parameters
Short run health effect for households that have not contracted diarrhea in the past year	-0.01 (-0.07; 0.041)	0.27	0.00
Short run health effect for households that have contracted diarrhea in the past year	0.07 (0.01; 0.14)	0.22	0.00
Long run health effect	3.27 (2.75; 3.90)	0.15	0.02

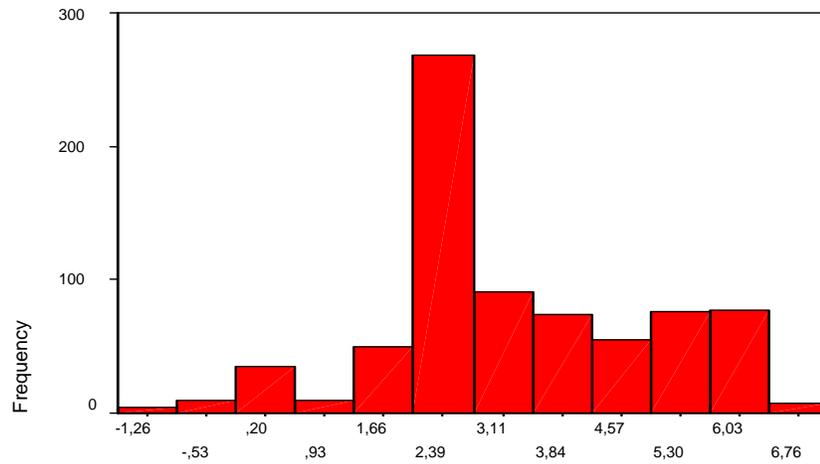
Since the coefficients of the attributes are normally distributed there is a probability that the marginal WTP will have the reverse sign. As can be seen in Table 5 these probabilities are actually non-negligible. However, as explained in Section 3 it is possible to derive individual-level parameters from the estimated model or, to be more precise, parameter distributions for different populations making a specific choice. This also means that we investigate how many individuals that have a reverse sign on their expected marginal WTPs. As can be seen in the last column of Table 5 this share is zero for the short run attribute and very small for the long run attribute. The individual-level marginal WTPs are also shown in Figure 2 below. The first two figures illustrate the household marginal WTP for the short run health effect for households that have not and have contracted diarrhea in the previous year, respectively. The last figure illustrates the WTP for a reduction in the long run health effect.

**Figure 2:** Household specific estimates of the willingness to pay (WTP).





Short run marginal WTP with diarrhea



Long run marginal WTP

The derivation of discrete welfare measures in CE is implicitly based on the assumption of alternative specific experiments, and involves the problem that the analyst does not know which alternative an individual would choose. Given certain assumptions, the welfare effect of a discrete change in the set of attributes can be expressed as the so-called log-sum formula (Hanemann, 1999):

$$WTP = \frac{1}{\delta} \left[ \ln \sum_{h \in A} e^{V_{h0}} - \ln \sum_{h \in A} e^{V_{h1}} \right], \quad (7)$$

where  $V_{h0}$  and  $V_{h1}$  are the utility levels before and after the change, respectively, for each alternative. However, in our case the CE has generic alternatives and we therefore suggest another, more intuitive way, of deriving the welfare measure. Since we can formulate any welfare evaluation as a binary choice, we do not have the

problem of not knowing which alternative a particular respondent would choose. We can therefore instead derive the WTP by solving the following equality:

$$\alpha_1 + \beta X_1 + \gamma_1 Z_h + \delta(y_h - WTP_h) + \varepsilon_{1h} = \beta X_0 + \delta y_h + \varepsilon_{0h}, \quad (8)$$

where  $X_1$  is the attribute vector after the change and  $X_0$  is the attribute vector for the opt-out (*status quo*). Since we included an alternative-specific constant for the non-opt-out alternatives, the constant is only included in the left hand side of the expression, together with the interacting socio-economic characteristics.<sup>3</sup> Mean WTP is then given by

$$E[WTP_h] = \frac{\beta(X_1 - X_0) + \alpha_1 + \gamma_1 Z_h}{\delta}. \quad (9)$$

This expression could have been obtained using the traditional approach with the log-sum formula by specifying only one alternative and a base case, so we are not arguing that our suggested approach gives a different result than the traditional one. The difference is that it is more straightforward and allows us to think in a simpler and more straightforward way about other functional forms that might be more suitable. Table 6 depicts the welfare estimates for a proposed improvement moving from the *status quo* to a 50% reduction in the short run effect and to a 2% long run risk. Standard errors are calculated with the Krinsky-Robb method with 1000 draws. As a comparison we also calculate the welfare effect not considering the alternative-specific constant (and consequently not the socio-economic characteristics that are interacting with the constant). The latter measure can be seen as a measure of the WTP given that they are willing to make a trade-off.

**Table 6:** Mean WTP for improvement in the short run of 50 percent and 2 percent risk in the long run in Egyptian pounds; 95% confidence intervals in parentheses.

	With intercept	Without intercept
Mean WTP	14.80 (8.64; 20.90)	28.07 (23.16; 33.88)

## 5. Discussion and conclusion

This paper presents, to the authors' knowledge, the first application of the CE analysis of health improvements through better water quality in a developing country

<sup>3</sup> Note that it is not necessary to include an opt-out alternative in each choice set to derive this measure. What would be recommendable is to include the opt-out levels of the attributes as possible levels.

context. The study asked the households to value a health risk that they had actually experienced (i.e. the short run effect) and a “synthetic” illness that the interviewers described to them. This provides information that can be used to better understand the structure of the benefits of water quality improvement or other health programs in metropolitan Cairo. The analysis of the social determinants of the willingness to pay can also be used to give insights concerning other issues such as designing health policy and tariff construction.

The estimated random parameter logit model shows that households in metropolitan Cairo have a positive WTP to reduce health risks related to water quality. The mean WTP concerning a 50% decrease in the short run health effect due to poor water quality, and a reduction in the probability of contracting waterborne diseases in the long run to 2% is found to be almost 15 Egyptian pounds per every second month. This corresponds to around 2.6 percent of the mean monthly income. We also find significant heterogeneity among the households, both in terms of observed characteristics such as whether they had contracted diarrhea in the last year or not, educational level, whether the household is female headed or not, but also in terms of unobserved characteristics. The latter is found by modeling a random parameter logit model, where we allow for heterogeneity in preferences regarding the attributes included in the choice experiment. We also illustrate the richness of information that can be obtained from this type of modeling approach by estimating individual level marginal WTP and, as mentioned, the mean WTP for a particular policy program.

However, the estimated WTP that we find in this paper seems to be fairly low compared with the costs of a program that would achieve these improvements. This low WTP could possibly be attributed to limitations in understanding health problems and their sources. Alternatively, it may reflect a psychological defense or misinformation, or the respondents’ beliefs that such problems are beyond their control. Nevertheless, to give some orders of magnitude the WTP is found to be approximately 37.5 USD per household per year and the cost of rehabilitation and upgrading water and sewage systems may be around 90-180 USD per household per year according to the World Bank (1995).

We believe that the CE as such proved to work fairly well in this context. The visual aids were helpful for the respondents and many respondents found the CE interesting and even fun. That the CE at least was not a failure is also indicated by the

fact that we find a significant observed heterogeneity and that there is a significant WTP for improvements in both short and long run health states.

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