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Willingness to Pay for Drinking Water in Urban Areas of Developing Countries

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Abstract

Many crowded urban centers in developing countries face potable water problems. A public or a market intervention could solve these problems. In order for an intervention to occur, it is necessary to determine the public's willingness to pay for safe drinking water services. In this paper a nested logit model is set up according to the options available to households for tap water treatment (e.g., boiling, filtering, and purchase of bottled water). The nested logit model yields parameters for a welfare estimation which determines the benefits from safe drinking water to households in the state of Espírito Santo, Southeast of Brazil.

1. Introduction

The increase in urban population in developing countries has augmented the pressure on natural resources (e.g., air and water) in these crowded centers. In fact, access to safe potable water is a problem. Many households in urban areas of developing countries shift significant resources into treating water for drinking consumption. A study done by the World Bank reveals that in Jakarta households spend more than $50 million each year boiling water, an amount equal to 1% of the city's GDP. In Brazil most households use a water filter to treat drinking water. The Brazilian Institute of Geography and Statistics (IBGE) in a national household survey of 31.5 million urban households conducted in 1995 revealed that 62% of the households use filters[i]; however, many people are still exposed to untreated water, thus, living with chronic diarrheal diseases. A public or a market intervention could cause a decline in the number of cases of diarrheal diseases and free labor used to boil or buy bottled water to more productive ends. In order for public or private institutions to provide water treated for drinking consumption, they need to know how much consumers value these services by finding out consumer's willingness to pay.

The defensive expenditures (defensive inputs) approach can be used to find out the willingness to pay for higher drinking water quality. Defensive inputs usually are market goods, e.g., air and water filters, which ease personal impacts of pollution. Although valuation methods which use defensive expenditures to estimate marginal benefits (damages) resulting from improvements (deterioration) in environmental quality have been applied, only Bartik's (1988) approach has been used to value non-marginal improvements in drinking water quality through the use of defensive inputs (Abdalla (1990); Collins and

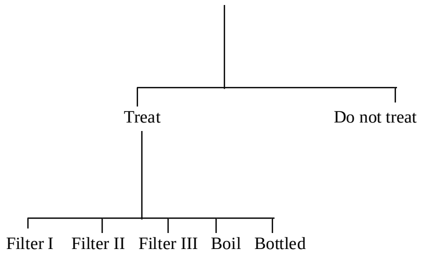
Steinback (1993); Abdalla, Roach, and Epp (1992); Harrington, Krupnick, and Spofford (1989)).

In this paper I use a nested logit model to get parameters for a welfare estimation of the benefits from non-marginal improvements in tap water quality in an urban agglomeration of Espírito Santo, a state in the Southeast of Brazil. The nested logit model is set according to the options available to households for tap water treatment (e.g., boiling, filtering, and purchase of bottled water). In order to gather data for this study, nine hundred and seventeen households answered a questionnaire that reveals their averting behavior practices and their socio-economic characteristics[ii]. The remainder of this paper is divided as follows. Section two presents the nested logit model. Section three presents the results and concludes the paper.

2. The Nested Logit Model

Many urban households in Brazil treat tap water for drinking consumption, mainly to protect against diarrheal diseased such as giardiasis and amoebiasis. Each household decides whether or not to treat the water they drink. They will treat it by boiling, filtering[iii], or they can purchase bottled water. Decisions like the one above, where there is a group of alternatives that are close substitutes, can be modeled in a nested logit framework. The nested logit model can be developed by assuming that the individual (household) has a utility function which has a deterministic term and a stochastic term; the later is not observable to the researcher and is treated as a random variable. Models with a deterministic and a random part are know as random utility models. In a nested logit model, the error term has an extreme value distribution. The two level nested logit model presented here explains a household choice of a drinking water treatment alternative. There is a total of six alternatives available (M=6): type I filter, type II filter, type III filter, boiling, purchasing bottled water, and not treating drinking water. The household chooses an alternative, ij, where í $\in$ limb and j $\in$ branch, subject to the restriction that the choice at the branch level has to be consistent with the choice at the limb level:

Figure 1.



The utility the household receives if alternative ij is chosen is

$$(1)\quad u_{ij} = v_{ij} + \varepsilon_{ij} \qquad \forall\ (ij) \in M,$$

where v is the systematic component of utility and ε_{ij} is the error term, known to the household but unobserved by the researcher. The ε's have a generalized extreme value distribution; thus, permitting a pattern of correlation among the errors associated with the alternatives. The indirect utility function above can be explicitly written as follows:

$$(2)\qquad v_{ij} = v(p_j, y, \text{time}, \text{familiar}, S) = \beta{*}(y - p_j) + \gamma{*}\text{time}_j + \delta{*}\text{familiar}_j + \eta_i{*}S.$$

p_j represents the cost of treating drinking water under the different options. The vector S is made up of socio-economic variables that vary over individual but are constant across alternatives (e.g., schooling, age, and income). Thus, the coefficients vector η_i must be made alternative specific to show that the covariates may have different impacts depending on the alternative. y represents income, and time gives the time spent boiling and purchasing bottled water. The covariate familiar is a dummy variable indicating how the household perceives the taste of drinking water treated by various methods, and it also indicates the familiarity of the household with the alternative.

The probabilities below are estimated using multinomial logit procedures.

At the branch level, one estimates the probability that a household will filter drinking water using one of the three different types of filter, will boil the water, or will purchase bottled water:

(3) $P_{j/i} = e^{[\beta*(y\text{-}pj) + \gamma*\text{time } j + \delta*\text{familiarj}] / (1-\sigma)} / \sum_j e^{[\beta*(y\text{-}pj) + \gamma*\text{time } j + \delta*\text{familiarj} / (1-\sigma)]}$

For example, $P_{5/1}$ gives the probability of choosing bottled water given that the household decided to treat drinking water. $P_{j/i}$ are estimated with one independent application of the multinomial logit. At this stage one recovers estimates o theβ, δ, and γ up to a scale factor (1-σ). From the results of (3), the following inclusive value is computed and incorporated as a variable in the limb level of estimation:

(4) $I_i = \ln (\sum_j e^{[\beta*(y\text{-}pj) + \gamma*\text{time } j + \delta*\text{familiarj} / (1-\sigma)]})$.

In choosing a type of treatment for drinking water, the variable of interest is cost of different treatment types. Given the nature of the conditional logit model, variables in the indirect utility function that do not change across alternatives cancel out during estimation. Thus their coefficients can not be recovered, e.g., age. Income is the only variable that varies with observations and remains unchanged across alternatives but does not cancel out at this stage; the coefficient on income is the coefficient on cost with a sign change, given the way income and costs enter the indirect utility function and the assumption of constant marginal utility of income. Other variables that change across alternatives, thus, entering the estimation at this level are time and familiar.

At the limb level one estimates the probability that a household will treat drinking water:

(5) $P_i = e^{\eta i*S + (1-\sigma)*Ii} / \sum_i (e^{\eta i*S + (1-\sigma)*Ii})$.

For example, P_2 gives the probability that drinking water will not be treated at all. In deciding whether or not to treat drinking water the variables of most interest are household characteristics which vary over households but remain constant over alternatives, e.g., age, schooling and income. The η‘s and (1-σ) are estimated at this level. The parameter σ provides an estimate of the similarity of the observed choices at the branch level of the three structure: The closer σ is to zero the less likely the independence of irrelevant alternatives assumption (IIA) would be violated, and the less likely a nested logit model is necessary. In relating the generalized extreme value distribution to stochastic utility maximization, a sufficient condition for a nested logit model to be consistent with stochastic utility maximization is that the coefficient of each inclusive value lie in the unit interval (McFadden 1978). Thus, having the coefficient of the inclusive value lying tin the unit interval explains how much is gained from estimating a nested logit model.

3. Results and Conclusion

The nesting structure presented in Figure 1. and equations (1)-(5) are used in the estimation of a nested logit model to recover the parameters in the models (Table. 1).

Four models are estimated. The following explanatory variables are used in the estimation: DUM1, DUM2, DUM3, DUMBOIL, DUMBOT, COST, TIME, FAMILIAR, DTREDUN, DTR65, DTRCHIL, and DTRDINC (Table. 2). The explanatory variables for Model 1 are: DUM1, DUM2, DUMBOIL, DUMBOT, COST, TIME, FAMILIAR, DTREDUN, DTR65, and DTRCHIL. Model 2 has the same variables as Model 1, except for FAMILIAR, which is excluded from Model 2. DUM2, DUM3, DUMBOIL, DUMBOT, COST, TIME, FAMILIAR, DTRCHIL, and DTRDINC are the explanatory variables in Model 3. FAMILIAR is excluded from Model 4, but all of the other explanatory variables in Model 3 are present here. At the branch level, the variables are significant across all models at the 5% significance level. At the limb level, all variables are significant at the 5% level, except for DTRCHIL and DTR65. DTRCHIL is significant only at the 10% significance level and only in Model 4. In Model 1, DTR65 is not significant at the 5% or 10% significance level. As shown in Table 2, about eleven percent of the households had monthly income greater than or equal to \$1,680. In only about twelve percent of the households, the head of the household did not have any schooling. There were children two years old and younger in sixteen percent of the households, and about seventeen percent of the households was home to people who were 65 or older.

The variable COST is used at the first estimation level (Branch Level). The variable COST incorporates time and variable costs for purchasing bottled water and boiling water. There are only variable costs associated with the use of filters. In order to come up with the time cost figures, it is assumed that people work 160 hours a month, that is 9600 minutes a month. Given that the questionnaire revealed monthly income for the household and for the maid when there was one, it is possible to calculate the wage rate by minute for the person in charge of treating drinking water; the opportunity cost of the maid was the one used when available. Multiplying the wage rate by minute times minutes spent boiling drinking water or buying bottled water reveals the time cost per month of treating drinking water. The time spent purchasing bottled water (TIME) was calculated as follows: The length of time that takes to go to the local market and return home was multiplied by the frequency of trips for households actually purchasing bottled water; for households not buying bottled water, a proxy for frequency was obtained by running a regression of frequency -for those households who actually bought bottled water- on a constant and the number of people in the household; with the parameter estimates from the regression and information on the number of people in the household available, the frequency of trips was calculated for those households not purchasing bottled water. In the case of boiling the water it is assumed that it takes four minutes to boil 1.14 liters of water, and according to Laughland et al. (1993), only one fourth of the four minutes is spent boiling; the remaining time is used for other activities, i.e., food preparation. Thus, dividing the amount boiled by 1.14 and multiplying the result by four yields minutes spent boiling water in a month (TIME). Households were asked about the amount of water they boiled or purchased. For households not boiling drinking water and not purchasing bottled water, the amount of drinking water consumed was calculated by assuming that a person drinks twenty-one litters of water in week --according to the ICRP (1975), minimum water requirements for fluid replacement have been estimated to be about three liters per day under average temperate climate conditions. The daily intake of drinking water was then multiplied by the number of people in the household.

The monthly variable cost for boiling water was obtained by multiplying the amount boiled in a week by $0.10[iv]. In order to get the variable cost of bottled water, the amount of drinking water consumed in a week was multiplied by the price of one liter[v]. Variable cost for filters was calculated by dividing the price of the filter[vi] by the number of years a household has had the filter[vii]. Monthly variable costs were found by dividing the annual cost by twelve. The monthly average cost of cleaning filters was also calculated for households which answered the variable cost question and applied to all households. The coefficient of COST is negative: The more an alternative costs the less likely it will be chosen. The coefficient on TIME is also negative; the longer it takes to treat drinking water with a given alternative, the less likely that alternative will be chosen. The coefficient on FAMILIAR is positive, indicating that if the household likes the taste of drinking water treated by a given alternative or if it is familiar with its taste then it is more likely that the given treatment type will be chosen. The coefficient on DUMBOT is always the largest one within a given model, indicating the preference for bottled water over other alternatives.

The DTR... are dummy variables taking on the value of one or zero. The DTR... variables consist of households characteristics that determine whether the households will treat drinking water or not. There is a set of parameters that determines whether or not drinking water will be treated for each alternative. Here the alternative chosen is no treatment. At the limb level, DTREDUN takes the value of one when the head of the household had no schooling. The positive coefficient indicates that households where the head had no formal education are more likely not to treat drinking water than to treat it. DTRCHIL is equal to one if there were kids two years old and younger in the household.

The coefficient on DTRCHIL is negative indicating that households with kids are less likely not to treat drinking water than to treat it. DTR65=1 if there were people who were sixty-five or older living in the household, 0 otherwise. DTRDINC=1 if the household monthly income was at or above $1,680, 0 otherwise. The presence of elderly in the household makes it more likely that drinking water will be treated; Thus, the negative coefficient on DTR65. The coefficient of DTRDINC is negative indicating that households with higher incomes are more likely to treat drinking water than not treat it.

The coefficient of the inclusive values at the second level of estimation lie in the [0,1] interval, indicating compatibility of the empirical model with utility maximization according to the global condition of Daly and Zachary, and McFadden (1979).

Welfare Estimation

Small & Rosen (1981) and Hanemann (1982) showed how to calculate welfare measures in the context of discrete choice models that are consistent with utility maximization. Here, the compensating variation (CV) measure is used. The compensating variation measure indicates the minimum amount of money a household is willing to accept for forgoing one of the options for treating drinking water. In order to find out the amount of money that compensates households when the boiling option is not present, the expected value of the maximum of indirect utility with all the alternatives present (i.e., the three types of filters, boiling, and purchase of bottled water) is set equal to the expected valued of the maximum of indirect utility without the boiling option:

(6) $E[V] = E[V_{-1}(y-p+ CV)]$,

where $V= \max [v_1(.) + e_1,..., v_5(.) + e_5]$ and V_{-1} indicates that the boiling alternative was eliminated. The household's willingness to pay for water of drinking quality is equal to the household's willingness to accept a compensation for eliminating boiling from the choice set. Boiling is chosen because it is the only alternative that does not cause joint production. Other options, i.e., filters or bottled water, produce higher drinking water quality and yield better tasting water. Thus, treatment options other than boiling enter the utility function; the presence of defensive inputs in the utility function is a form of joint production. With joint production it is not possible to recover meaningful measures of willingness to pay.

The compensating variation measure is calculated for each household in the sample. By examining how much a household is willing to accept for having the option of boiling eliminated, it is possible to determine how much it is willing to pay for water of drinking quality. The compensating variation measure recovered here is only a lower bound to the benefits to a household from receiving tap water treated for drinking purposes; higher environmental quality is less than a perfect substitute to expenses with defensive inputs: All faucets in the house -not only the kitchen faucet- would receive treated drinking water after the improvement in water quality and the value of this benefit is not revealed by expenses in treatment options of point of use sources.

Households are willing to pay on average an additional $0.98 a month in order to have safe drinking water when all the options are present in calculating (6) and the boiling alternative is excluded from the right hand side of (6). Given that there are about 481,147 households in urban Espírito Santo[viii] and urban households are willing to pay $0.98 a month for higher drinking water quality, the annual benefits to the urban population in Espírito Santo from having improved drinking water quality is $5,658,289[ix]. The minimum amount of money they are willing to pay for safe drinking water when they do not have the option of purchasing bottled water (the option of purchasing is dropped from both sides of (6) and boiling is dropped only from the right hand side) is $30.69. Thus, the annual benefit to the urban population of Espírito Santo is $177,196,817.

Conclusion

Pollution of the environment, e.g., air and water, has become a pressing problem in urban centers of developing countries. The population growth in these centers augments potable water problems. Many households in developing countries treat the water supplied to their houses before drinking it. This imposes costs on society and slows productivity. In order to supply water of drinking quality to the population, it is necessary to know how much they value the service. The empirical literature on valuation of nonmarginal benefits from improvements in drinking water quality does not present a variety of methodologies to determine the benefits using defensive expenditures. Most of these papers use Bartik's theoretical set up. In this paper a discrete choice model, the nested logit model, is used to yield the parameters for a welfare estimation; these parameters are used to reveal the amount of money that compensates a household when the boiling option is eliminated in two different scenarios: 1) with all the alternatives available; 3) without the bottled water option.

Table. 1 Parameter Estimates from the Nested Logit Model

Variables	Model 1	Model 2	Model 3	Model 4
Branch Level: Filter I, Filter II, Filter III, Boil , or Bottled				
DUM1	-0.7514**	-1.2596**	--	--
	(-3.058)	(-5.303)		
DUM2	0.9961**	1.1638**	1.7475**	2.4234**
	(8.549)	(10.378)	(7.400)	(10.721)
DUM3	--	--	0.75138**	1.2596**
			(3.058)	(5.303)
DUMBOIL	2.8210**	2.2829**	3.5724**	3.5425**
	(7.104)	(6.113)	(8.406)	(8.692)
DUMBOT	3.4950**	3.6618**	4.2464**	4.9214**
	(7.380)	(7.975)	(8.677)	(10.8381)
COST	-0.0843**	-0.0851**	-0.0843**	-0.0851**
	(-7.441)	(-7.565)	(-7.441)	(-7.565)
TIME	-0.0082**	-0.0075**	-0.0082**	-0.0075**
	(-3.848)	(-3.599)	(-3.848)	(-3.599)
FAMILIAR	1.5311**	--	1.5311**	--
	(8.381)		(8.381)	
	Limb Level:	*Treat Vs. Do not treat*		
DTREDUN	1.1644**	1.2259**	--	--
	(3.689)	(4.147)		
DTR65	-0.4332	-0.5908**	--	--
	(-1.454)	(-2.028)		
DTRCHIL	-0.3481	-0.4413	-0.4555	-0.5798*
	(-0.865)	(-1.098)	(-1.427)	(-1.903)
DTRDINC	--	--	-2.9254**	-3.0880**
			(-2.871)	(-3.043)
INCL.VALUE	0.7208**	0.9928**	0.4536**	0.4412**
	(3.753)	(2.261)	(4.162)	(3.704)

Note: ** indicates significance at the 5% significance level. * indicates significance at the 10% level. The numbers in parenthesis are t-ratios.

Table. 2 Definition and Mean of Variables used in the Nested Logit Model

Variable	Definition	Mean (frequency)	#obs.
	Branch Level		
DUM1	choice specific indicator for filter 1	0.2	3510
DUM2	choice specific indicator for filter 2	0.2	3510
DUM3	choice specific indicator for filter 3	0.2	3510
DUMBOIL	choice specific indicator for boiling	0.2	3510
DUMBOT	choice specific indicator for bottled water	0.2	3510
COST	cost of treating drinking water by the 5 options	$28.88 p/ month	3510
TIME	time spent boiling water & purchasing bottled water	88 min p/ month	3510 3510
FAMILIAR	=1 if taste is good; 0 otherwise and when household is not familiar with the taste of the water treated by a specific option.	0.57	3510
	Limb Level		
DTREDUN	=1 if head of household received no schooling; 0 otherwise	0.12	702
DTR65	=1 if people who are 65 years old and older are present; 0 otherwise	0.17	702
DTRCHIL	=1 if children who are 2 years old and younger are present; 0 otherwise	0.16	702
DTRDINC	=1 if household has monthly income at or above $1,680; 0 otherwise	0.11	702

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[i] Only 12% of the urban population does not have piped water according the 1991 census.

[ii] The data comes from a World Bank project.

[iii] Three types of filters are frequently used to treat drinking water in Brazil: I eliminates bacteria (e.g., the bacteria that causes cholera) and cysts of parasites like giardia and amoeba; II and III only eliminate the cysts.

[iv] According to the Pan-American Health Association, it costs between two and ten cents to boil one liter of water depending on the fuel used (firewood, coal, charcoal, gas, or electricity).

[v] Price was revealed in the questionnaire. If price was not available, it was determined to be $0.25 p/ liter in this sample.

[vi] Price of Filter I was $150; $80 for Filter III and $30 for Filter II.

[vii] The average duration of Filter I and Filter III in this sample was four years; six for Filter II. For households without filters, it was assumed Filter II -given its popularity- would have been the one chosen.

[viii] There are about 1,924,588 people in urban Espirito Santo according to the 1991 Census by the Brazilian Institute of Geography and Statistics (IBGE), and I assumed that the average household size is four people.

[ix] $5,773,764=(481,147*$0.98)*12

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