DEMAND FOR A HOUSEHOLD WATER SUPPLY SYSTEM IN A COMMUNITY SITUATED IN TAUÁ-CEARÁ

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ABSTRACT

The purpose of this study is to estimate how much the families of a typical rural community in Ceará would be willing to pay (WTP) for a potable piped water supply system. Moreover, this work analyzed the strategies used by people in order to obtain water, at a place where there is a high scarcity of water. All the data were collected in March 1999 during a research held in *Poço da Onça*, a community in the Tauá area (Ceará State), where we can find 126 households and a public brackish water tap. Residents spend, on average, R$ 12.15/month on potable water, which is collected at distant sources. By the logit model, this study estimated that families would be WTP R$15.61/month for an improved potable piped water supply system. It was also confirmed that the users' water storage capacity, their bonds of kinship and time of the year are factors that should be always considered by water supply policies to influence the type of solidarity as much as the several kinds of conflicts.

Key words: water demand, water supply, logit model

1. Introduction

The 1990 Global Conference on Safe Water and Sanitation took place in New Deli. Because many rural households in developing countries are too poor, it was assumed in the declaration of the New Deli Conference that improved water systems should be subsidized by the government.

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The Conference conceptual implications have not been universally welcomed by many individuals in the World Bank, who proffer an alternative *second standard* paradigm (WORLD BANK WATER DEMAND RESEARCH TEAM, 1993). They contend that people can and are willing to pay at least 3 to 5 percent of their income for improved water services.

While this discussion continues, millions of people in the Brazilian northeast still face problems in obtaining potable water. They usually go long distances to collect water every day (not always of good quality) or they depend on tanker truck operators.

Moreover, the unsuitable water use is one of the major factors in the aggravation of the northeastern health standards. Consequences for productivity and quality of life are obvious, making all the strategies to combat poverty useless.

The situation is still more dramatic in Ceará, both for the scarcity of water and for its quality. The groundwater obtained from 40% of examined wells in Ceará[2] (13,200 wells) is saline (> 1000 mg/l of saline solution). For more than one million Cearenses this water is unsuitable for drinking.

Many studies, such as Singh et al.'s (1992), have concluded that the current water supply situation in the rural Third World can be described as a *low-level equilibrium trap*. According to it, people demand water more and more while systems provide a low level of service with few taps. In addition, consumers are not willing to pay much for the water supply and authorities cannot charge real prices.

Since the World Bank is the principal financial institution of rural water supply systems in Third World countries, its interest in the economic feasibility is only natural. According to Briscoe et al. (1990), nearly all the strategies for tackling the problem have been supply-driven. The importance of water demand in the selection of appropriate policies has been virtually ignored.

2 This survey was carried out by the Companhia de Pesquisas de Recursos Minerais - CPRM, in 1997-98.

Little research has been undertaken to examine the water supply systems valuation. As a consequence, this lack of information has impeded the elaboration of analyses that would guide to the fixation of more realistic tariffs. The recent demand-side information required is a change in the World Bank policy perception about the financing of a water supply system for urban provisioning (Pinheiro, 1998).

Thus, this study seeks to estimate households' willingness to pay (WTP) for an improved water supply system in a typical community in the Ceará Semi-Arid region.

Moreover, this study is part of a wider research program called WAVES[3] PROJECT. Such research adopts a multidisciplinary approach that seeks to generate scientific and technological knowledge in the Semi-Arid region, specifically in the following counties: Tauá (Ceará State) and Picos (Piauí State). This project is a collaboration between researchers from Brazilian universities (Federal University of Ceará and Federal University of Piauí) and Germany universities (Kassel and Munich Universities).

One of the WAVES PROJECT interdisciplinary research efforts focuses on the household water supply in rural communities. In order to support household water supply policy planning, this study proposes to document the following themes: i) people's effort to collect water; ii) dispute and/or solidarity among households in rural communities concerning about water access and distribution. Thereby, the goal of this study is both to estimate the WTP and to recognize and examine sociocultural matters that are related to the WAVES PROJECT studies.

2. Methodology

2.1. Site Selection

This study was carried out in the Tauá region, specifically in a community called *Poço da Onça*, in March 1999. About 150 houses

[3] Water Availability of Ecosystem and Society in Northeastern Brazil

were found there. The most of the year, its population consumes brackish water.

There are 501 residents in *Poço da Onça*. Most of these people work for farm owners on a daily payment basis. A few rare landowners own a small amount of land used for subsistence crops farming and caprine/ ovine raising activities.

Appendix 1 shows that residents, on an average, have five years of education. The analyses of the questionnaire responses also showed that 43% of the heads of households are unlettered. An important factor is that young people have higher educational levels: youths aged up to 15 have, on an average, 5.3 years of education. The children's enrollment rate at school is 80 % and school drop-outs rate is low.

Heads of households' average age is 47.9 years and there are, on an average, four people living in each home (Appendix 1). In addition, 62 % of households have one or two members of their family, mainly aged between 18 and 30 living outside their community. The current migratory movement from the country to the cities is intensified within the Ceará State itself, mainly to Fortaleza, although most of these people have already lived in other States.

The monthly *per capita* income is R$ 39.81 and almost half the families depend on a retirement pension (Contribuição Especial da Seguridade Social Rural - CESSR, know before as FUNRURAL)) for a living. Moreover, there is a high proportion of senior citizens as well as children compared to the ones at working age. About 31 % of the *Poço da Onça* population are underage. There is 1.5 person per room in 90 % of the households and 12 % of the households do not have electricity. It is important to examine the fact that 64% of the households have radio and TV, and 15 % have only radio.

2.2. Contingent Valuation Method

Economic measures have the advantage of counting all activities in the same unit of value: money. This allows the valuation of millions of individuals to be combined into a single number without having to survey them. Moreover, recorded market transactions measure the values of billions of choices made every day. In addition, it is often possible to estimate the value of an activity as if there were a market for it.

The absence of equilibrium markets for public goods and services makes it difficult to measure the demand for the kinds of services that the government offers. Thus, it is troublesome to use consumption in this sector as a proxy for valuing goods and services provided.

Contingent valuation studies have been used to value public goods and other non-marketed commodities. The essence of contingent valuation method (CVM) is the specification of a hypothetical market for a non-market commodity and a query to individuals regarding the value placed on the increments of that good. In other words, a contingent valuation survey simply asks people an open-ended question about how much they would be willing to pay for the commodity under consideration.

Davis (1963) is known for having applied the CVM for the first time. It became a subject of general interest with the development of the natural resources economy. However, the usefulness of CVM in valuing public goods was first demonstrated by Randall et al. (1974). According to Mitchell & Carson (1989), the aspect of the CVM involves three stages: i) performing a detailed description of the commodity under consideration; ii) getting information on the WTP for the commodity; and iii) soliciting sufficient information on relevant socioeconomic parameters of the consumers.

2.3. Econometric Model

Installing a piped water supply service in a community means a benefit for its population, increasing its well being. Such proposal would be expected to ratchet up the consumers to a high-level equilibrium and utility. Now one could ask how much each consumer is WTP for such improvement.

In studies of water demand carried out in Brazilian rural communities, Briscoe et al. (1990) take into consideration following linear utility function for each person:

$$U_{ij} = \alpha_0 + \alpha_1 p_j + \alpha_2 y_i + \alpha_3 z_i + e_{ij} \tag{1}$$

It is assumed that an individual chooses between two water sources (j) based on maximizing two conditional indirect utility functions. The first one describes the utility gained from using the new source ($j = 1$), and the second the utility derived from using the current source ($j = 0$). In each case, the observed utility, U, for a particular individual, i, of a particular source depends on price, p, income, y, a set of socioeconomic variables, z, and an error, $e_{ij.}$

The theoretical formulation of Haneman (1984), presented as follows, allows for an estimation of the monetary value of non-marketed goods/services benefits in real markets using a binary response data.

If an individual is willing to pay a price p for a service, after inserting the binary variable j in the utility function and also the socioeconomic ones, we have:

$$u_1 \, (1,y\text{-}p;z) \geq u_0 \, (0.y;z); \tag{2}$$

Thus, u_1 and u_0 are random variables with probability distribution and means $v\,(1,y\text{-}p;z)$ *e* $v\,(0.y;z)$. Equivalently, they can be written as:

$$v\,(1,y\text{-}p;z) - v\,(0.y;z) \geq e_0 - e_1; \tag{3}$$

The result is a random variable whose probability distribution is given by:

$$P_1 = Pr\,[v\,(1,y\text{-}p;z) + e_1 \geq v\,(0.y;z) + e_0\,]\,; \tag{4}$$

where $$P_1 = Pr\,[\,\Delta v \geq \varphi\,]\,; \tag{5}$$

and; $$\Delta v = v\,(1,y\text{-}p;z) - v\,(0.y;z)\,; \tag{6}$$

being $\varphi = e_0 - e_1$, and finally, $P_0 = 1 - P_{1.}$

Since $P\varphi\,(.)$ represents the accumulated distribution of φ, the probability that an interviewee is WTP for the commodity price mentioned is:

$$P_1 = P_\varphi\,(\Delta v) \tag{7}$$

Thus, $P\varphi\,(.)$ is a difference in utility under the functional form:

$$v\,(j,y;z) = a_j(z) + by \qquad \text{being: } j = 0.1,\ e\ b > 0; \tag{8}$$

while: $$\Delta v = a1(z) + b(y-p) - ao(z) - by$$

$$= a^* - bp \tag{9}$$

Considering that φ has a standard logistic distribution, the mean equals to zero at the point where $P\varphi\,(0) = 0.5$ and where the individual is indifferent at accepting or refusing the offer proposed. Thus, p satisfies ($a^* - bp = 0$), resulting in:

$$p = \frac{a^*}{b} \tag{10}$$

2.4. Logit Model

The logistic distribution function may be written as:

$$P_i = \frac{1}{1+e^{-Z_i}} \tag{11}$$

Where: $$Z_i = \beta_1 + \beta_2 X_i \tag{12}$$

and, $$P_i = \frac{1}{1+e^{-(\beta_1+\beta_2 X_i)}}. \tag{13}$$

Z_i is defined between - ∞ e + ∞; P_i is between 0 and 1. If the dependent variable is binary, the estimation by the ordinary least squares (OLS) is not possible (Pindyck & Rubinfeld, 1981). When an individual consents to pay the price, P_i is the "yes" response probability. When an individual refuses otherwise, 1 - P_i is the "no" response probability. Thus, these probabilities may be written as:

$$\frac{P_I}{1-P_I} = \frac{1}{1+e^{Z_I}} \tag{14}$$

$$L_i = ln\left(\frac{P_i}{1-P_i}\right) = Z_i \tag{15}$$

Equation (15) shows the logarithm of the two probabilities division as a dependent variable, which can accept any value, even if P_i is between 0 and 1. Logit interpretation is: β_2 measures the change in L_i, when of an unitary variation in X_i. In addition, L_i is linearly related to the following variables:

$$L_i = \beta_1 + \beta_2 p + \beta_3 y + \beta_4 t + e \tag{16}$$

The independent variables included in the model are: p = monthly tariff that families would be willing to pay (WTP) for the water supply system, in R$/month; y = *per capita* average income, in R$/month; t = number of people living in the respondent's house, and e = error. Finally, it is expected that β_2 is negative, β_3 and β_4 are positive.

2.5. The Appropriation Mode Water Distribution

A water supply policy should not be based only on economic judgments. In addition, other sets of characteristics jointly influence a household's willingness to pay, such as: socioeconomic and technological characteristics.

The appropriation mode concept of natural resources represents a wider form to approach these aspects. According to Troadec (1990), the appropriation mode and sharing of natural resources are the subject of interest to the research program, mainly from the perspective of future management.

A good management may always satisfy the several kinds of demands with the least cost and promote behaviors and positive attitudes among the participants.

This theoretical approach presented here provides a framework for the identification and introductory analyses of devices and existing strategies, adopted in a given community, in order to guarantee the resource availability in terms of quantity and quality.

The Weber & Bailly's (1997) theoretical principals say that, in all societies, anthropologists found out that scarcity is socially constructed by the necessity selection and by the use of specific goods, as social status approval.

Thereby, the subjects focused in this study are: behavior and attitudes which assure social status; water appropriation mode and water sharing, including forms of solidarity and reason of conflicts; water source sites per kind of use; and, costs of acquisition or extraction, as a measure of the effort to collect water.

3. Research Data

All the 126 household families in *Poço da Onça* were interviewed. A questionnaire was made in order to attend both necessity of information on the WTP estimates and water appropriation mode study. Family's data consisted of socioeconomic characteristics including family size and composition, occupation, age, education, income and assets; and characteristics of the current water source, including perceived quality, both expenses and time required to collect water, monthly water consumption per source and destination, and storage capacity. Finally, a scenario of the water supply system was suggested to query their preferences. The scenario consisted of the following characteristics: i) potable water; ii) available in quantity 24 hours a day; iii) users should be monthly charged for the service; iv) water consumption should be measured; v) a pipe should be installed, a tap located inside the house; vi) users would not pay for the household connection to the distribution system; and vii) water could only be used for household purposes and never for watering animals or crops.

First, the *referendum* method was used, presenting the respondents prices ranging from R$ 7.00 to R$ 35.00, and asking them to indicate what choice they would make: "yes" or "no" (Mitchell & Carson, 1989). Afterwards, a set of connected questions was asked to make respondent state the price for the water supply system described.

The research was planned to generate 9 observations represented by arranged data. Thus, each group of 14 families answered whether they would be willing or unwilling to pay different amounts for the piped water improvements in their households. The first group was submitted the price of R$ 35.00/month, which was gradually reduced to R$ 3,50/month until the last group was asked the price of R$ 7.00 per month.

4. Result and Discussion

4.1. Willingness to Pay for Improved Water Supply System

The parameter estimates and statistics of the logit model are reported in Table 1 and expressed by:

$$L = 1.707 - 0.094\,p + 0.032y - 0.252t \qquad (17)$$

Price variable coefficient (p) is negative and statistically significant at 1%. Consistent with a priori expectation, it suggests that an additional 1 real in the pricehouseholds would monthly pay for the proposed system reduces the logarithm of the probabilities division by 0.094, if the setting price is accepted.

The results also confirm that individuals with higher income level are more likely to be WTP for the proposed monthly water supply tariff.

Estimate of the *t*-statistics is significant in one-tailed test and it has negative sign, unlike the priori expectation. It suggests that larger families are much more resistant to paying for a given proposed water supply tariff than smaller families. Probably, determinants such as high unemployment rate and low households' average income may have some bearing on households' WTP for improved services.

In order to make a WTP prediction from (17), investigations can be made such as: supposing the monthly average income of a family of three members is R$ 120.00, what would be the probability of accepting a monthly R$ 10.00 tariff for the water supply system proposed to replace the current one?

To answer this kind of question, let *p*, *y* and *t* have the values 10, 40 and 3 respectively, in equation (17), and we will find L = 1.291. Assuming that the antilogarithm of L = antilogarithm of (P/1-P) = 3.6036, the estimated probability is 0.784. It means that 78.4% of families would be WTP for the monthly amount of R$ 10.00 for the water system proposed.

Table 1 - Results of the adjusted "LOGIT" regression

Results	Coefficients	Standard error	*t*-statistics	Probabilities
Constant	1.707	0.937	1.819	0.218
p	-0.094	0.011	-7.978	0.0004
y	0.032	0.015	2.105	0.089
t	-0.252	0.131	-1.921	0.112
		$R^2 = 0.96$; F = 47.01		

Source: Research data

The obtained parameters can be used to estimate the benefits[4], considering the distribution previously described in (10). Thus:

$$\text{Benefit}\ (p) = \frac{1,9578}{0,094} = 20.82$$

The families would be WTP R$ 20.82/month for the water system proposed during dry years. However, in years of normal weather there is natural rainwater availability in the period from February to April. Thus, the WTP would be = R$ 20.82 x ¾ = R$ 15.61/month.

4.2. Adopted Strategies for Water Collecting and Distribution

The families carry and store 83 liters of water per day at home (TABLE 2). The number of families that use water at their own houses, in the several modalities, vary significantly. People only use well water located right in the community, for drinking or cooking, in times of extreme water shortage. The groundwater salinity is 6,200mg/l of saline solution. Other water uses justify the sacrifice of collecting water from a dam at a distance of 2 km from the community. Even so, this water saline solution is 4,800 mg/l, being the limit recommended by OMS.

Users almost always use saline well water for cleaning and bathing, and 32% of water carrying service is done by women. People say that well water is not hygienic and they would rather go right to the water source (dam, creek or saline wells) for washing clothes and dishes than doing it at home.

Local power lies in the person who controls the water. The more a water tank is in size and in quality, the more likely a household's status would be to have it. This study showed that the degree of kindred is the principal factor of solidarity among residents. In addition, the gradual increase of scarcity of water along the year lies at the heart of conflicts.

[4] The denominator is the variable coefficient (p) and the numerator is the constant number added to the average value of each one of the other variables multiplied by their coefficients.

Table 2. Daily average quantity water home delivered, per water use practice, number and percentage of family users.

Water use practices	Drinking	Cooking	Washing-up	Washing Clothes
Quantity (l/day)	11.4	13,4	48	18
Number of families	92	87	11	14
Families (%)	73	69	8.7	11

cont.

Water use practices	Cleaning	Bathing	Not specific	Average
Quantity (l/day)	12.2	36	73	83
Number of families	126	82	26	-
Families (%)	100	65	20.6	-

Source: Research Data

To facilitate the analysis, the year was divided into three periods. Period I covers the months from February to April, when two thirds of the annual precipitation fall on the ground. About ten percent of the families have water tanks with capacity above $10m^3$. These people consume water from rainfall or tanker trucks sources. In general, families use good-quality water during the rainy season. There is a high level of solidarity among them, regardless of their degree of kinship with households' private water tanks. This is due to the rain function as an easy water replacement source.

Period II covers the next four months after the rainy season, from May to August. During this period we can find a medium level of solidarity. Only families with some degree of kinship with households' private water tanks are able to consume good-quality water. In part, the tank owners fall back on tanker truck operators for restoring water. The ones who have median-sized tanks also use dams and wells for restoring water which is not very suitable for drinking. Eighty-four percent of people who are not able to store water do not have access to potable water.

Period III starts in September and finishes in January. A low level of solidarity among the families characterizes this period. Those who do not have tanks consume doubtful-quality water or are forced to drink brackish water from the public tap. During these months, the regular water sources are completely dry or with little water supply, being eventually consumed by animals.

The effort of obtaining water was measured by the cost in collecting it from existing sources whose water volume will depend on the user's storage capacity.

Small water tank owners, up to 1m^3 capacity, are daily forced into bringing water from distant sources, during 9 months within the Periods II and III. The water payment is based on the labor opportunity cost and, according to the research data, each family spends, on an average, one hour per day to carry water. The water source is common to all, differing the mode of home delivery. It is transported by animals, tanker trucks or on foot. It represents four working days a month, costing R$ 3.50 each, resulting in an annual cost of collecting water of:

R$3.50 x 4 working days x 9 months x 107 families = R$ 13,482.00.

There are only seven families with median-sized water tanks, 1-10 m^3 capacity, whose water is transported by median-sized tanker trucks (7 m^3 capacity) that deliver it twice per semester at a cost of R$ 3.57/ m^3. During the first three months of Period II, people use the remaining water from the rainy season for drinking and cooking. Consumers supplement their regular supply by obtaining, on a daily average, two containers (18 liters of water per container) of water from distributing vendors, at a price of R$ 0.25/container, resulting in an annual cost of:

(R$ 25.00 x 2 tanker trucks x 7 families) +
+ (R$ 0.25 x 2 containers x 270 days x 7 families) = R$ 1,295.00.

Residents who have water tanks bigger than 10 m^3 capacity can make reasonable rainwater storage. They guarantee water supply for all purposes during the 3 months interval of Period III. Afterwards, each family acquires, on an average, 75 m^3 of water to supply itself during the dry season. Transportation is made by tanker trucks, at a price of R$ 4.00/m^3. It is possible that water tank owners speculate in water during water shortage, having the distributing vendors an intermediary role in the negotiations. However, this cannot be confirmed.

The acquisition occurs during the 5 months of Period III, summing up:

R$ 4.00 x 15 m^3 x 5 months x12 families = R$ 3,600.00

The water annual expense to provide residents in *Poço da Onça* with basic needs is R$ 18,377.00. This amount means, on an average, R$ 145.85/year for each household or R$ 12.15/month.

5. Conclusion

This study indicated that families in *Poço da Onça* have assigned a high price to potable water coming from a suitable supply system and they are willing to pay different sums of money according to dry or normal weather occurrence. Nowadays, residents in *Poço da Onça* agree to reserve part of their income to make potable water affordable. This amount of money is vastly superior to what international financing organizations has stipulated for other poor rural areas in the world.

The conclusion is that, where difficult potable and/or brackish water source accessible to people predominate, we can find a water market and large losses of effort to get water, which means an increasing WTP for piped potable water. Besides that, if the monthly average cost of a water supply system suitable for this community is higher than R$ 15.61/month, the difference should be subsidized by the government. The families are willing to pay for the costs if they range between R$ 12.15 and R$ 15.61 per month. If monthly average costs per family range up to R$ 12.50/ month, the benefits for the community will be obvious because families already spend, on an average, this amount at the current system, which provides doubtful-quality water.

Finally, there is evidence that water storage capacity is perhaps the principal source of social status of a family in the community. Factors such as the degree of kinship among users, and the growing tendency for water to be scarce along the year, have an effect on the several ways of solidarity and, in certain circumstances, represent potential sources of conflicts. These are aspects that impose the modes of collecting, using and distributing the water along the time. Thus, these factors, besides the WTP estimate, should always be mentioned in the process of formulating potable water supply policies in the semi-arid rural communities.

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Apendix

APENDIX I - SOCIOECONOMIC CHARACTERISTICS OF HOUSEHOLDS IN POÇO DA ONÇA-TAUÁ – MARCH 1999
(MEAN VALUES PER GROUPS OF 14 FAMILIES)

Price (R$)	(*)Response YES	Family size	Age of household head (years)	Years of formal schooling	Per capita income R$/month	Number of people per room	Presence of radio and TV (%)	Collecting water time (min)	Capacity of storage (m^3)
7.00	12	3.26	50	3.86	40.95	1.4	64	62	110
10.50	11	4.38	51.4	5.43	52.02	1.25	57	49.29	2,180
14.00	8	4	52.8	5.57	37.84	1.5	21	52.21	120
17.50	9	3.86	47.9	6.29	48.02	2.5	57	56.79	2,941
21.00	7	3.98	52.8	5.86	34.08	1	79	97.14	3,214
24.50	4	5.19	49.6	5	37.02	1	93	36.43	1,032
28.00	4	3.27	33.1	4	34.07	1.5	64	56.5	1,054
31.50	5	3.51	49	4.14	45.11	1.5	57	53.08	1,947
35.00	2	5.42	44.7	5.43	30.03	1	86	53.58	4,157
					THE MEAN				
21.00	-	4,096	47.9	5,064.4	39.81	1,405.6	64	57.45	1,862

SOURCE: RESEARCH DATA
(*) Number of families that agreed to pay an amount of money for the proposed system, within a group of 14 families.

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