THE WORLD BANK ECONOMIC REVIEW, VOL. 4, NO. 2: 115-134

Toward Equitable and Sustainable Rural Water Supplies: A Contingent Valuation Study in Brazil

John Briscoe, Paulo Furtado de Castro, Charles Griffin, James North, and Orjan Olsen

Because many rural people are poor, it is usually assumed that rural water supplies must be financed by government agencies. It is now widely recognized, however, that many rural people can and will pay for improved water supplies, and that sustaining and extending services depends on mobilizing this willingness to pay. This article describes a study of willingness to pay for water in Brazil. The study shows that surveys of actual and hypothetical water-use practices can provide policy-relevant information on willingness to pay, which is shown to vary according to household socioeconomic characteristics and the characteristics of the existing and new supplies of water. In rural Brazil, tariffs for yard taps can be increased substantially before significant numbers of households would choose not to connect to an improved system, whereas provision of free water at public taps can protect the poor without jeopardizing the financial viability of the scheme.

Billions of people in developing countries face daily problems in obtaining water for drinking, cooking, bathing, and washing. More than 1,500 million people—30 percent of the world's population—are estimated to be without access to uncontaminated water; and an unknown but large proportion have to spend hours daily to collect water (Briscoe and de Ferranti 1988, Churchill 1987). Because the adverse consequences for productivity, health, and quality of life are so obvious and so widespread, extensive efforts have been mounted

John Briscoe is a unit chief in the Water and Sanitation Division, Infrastructure Department, the World Bank. Paulo Furtado de Castro is an economist at the Institute of Social and Economic Planning, Brasilia, Brazil. Charles Griffin is an associate professor in the Department of Economics, University of Oregon, Eugene, Oregon. James North is a graduate assistant in the Department of Economics, University of Oregon. Orjan Olsen is the research director of the Brazilian Institute of Public Opinion and Statistics (IBOPE), São Paulo, Brazil. The IBOPE team, comprising Marcia Cavalcanti Nunes, Olival No'boa Leme, Hélio Gastaldi Filho, Fredimar Alex Vasconcelos, and Lidio Shimizu, made major contributions to the design and execution of this study. The authors have benefited from numerous discussions with colleagues including Wilton Bussab, Emilio Rodriguez, V. Kerry Smith, and Dale Whittington. Financial support was provided by the United Nations Development Programme, the Swiss Development Corporation, the Norwegian Agency for International Development, the World Bank, and the government of Brazil.

to correct this problem, with increased emphasis since the inauguration of the United Nations' International Drinking Water and Sanitation Decade in 1981.

Most of these efforts have been based on the observation that the unserved are mostly poor people and on the assumption that these people cannot afford to pay for improved services. Accordingly, it has been concluded that services can be sustained and coverage increased only by mobilizing more public resources (from external support agencies and governments), by stretching the limited resources as far as possible by providing only a low, "basic-need" level of service, and by minimizing the cost of providing a given level of service.

The result of this sector philosophy has been that these water supply systems provide a low level of service (usually through public taps or hand pumps); they are heavily dependent on (often unreliable) government investment financing and transfers for operations and maintenance expenses; and the quantity and quality of service are unreliable.

The results are predictable. These "improved" systems often do not function: it is estimated that one in four systems is not working at any one time, and that the number of systems being abandoned is approximately equal to the number of systems being commissioned. And even if they do function, often they are not used. In Côte d'Ivoire and Kenya, for instance, surveys have shown that only one-third of the population reported to have access to improved facilities actually used them. The result is that the wealthier invest in individual supplies to secure a reasonable quality and reliability of service, while the poor are thrown back on traditional sources which often entail substantial time, health, and even monetary costs.

In recent years many have realized that precisely because the benefits of improved water supplies are so great, many people in developing countries can and will pay for improved services. They will do so, however, only if they are provided with services which, in their eyes, constitute significant improvements over their existing supplies. Now the challenge is to identify, under a range of socioeconomic and environmental conditions, the level of service that people want and for which they are willing to pay.

I. Why Demand Studies from Industrial Countries Are of Limited Relevance

There is a large literature on water demand in industrial countries, with most studies pertaining to single-family residences in the United States (for example, Jones and others 1984). The focus of this literature is on the estimation of income and price elasticities of demand. The majority of investigations of water demand in developing countries have been modeled on this industrial-country literature (for example, Inter-American Development Bank 1985a, 1985b, 1985c, 1985d; Katzman 1977; and Hubbell 1977).

The economics of water utility management in an industrial country is a relatively simple matter. All potential users will connect to the system, and all will have multiple taps in their yards and houses. Because the quantity of water used is relatively inelastic with respect to price, future needs and revenues for a given tariff can be projected with some confidence. In a developing country the situation is considerably more complicated. The number of potential users who will choose to connect to a system is heavily dependent on exogenous factors (such as the family's socioeconomic situation, and the cost and perceived quality of their existing sources, including accessibility, reliability, and aesthetic characteristics), as well as on factors controlled by the utility (such as the level of service offered, the connection cost, and the tariff charged).

There are obvious dangers inherent in designing rural water supply systems without reasonable information on what services people want and for what they are willing to pay. On the one hand, in many cases facilities are built for which a community would never pay. This is the case, for instance, in the rural communities in Zimbabwe that participated in this multicountry study (Robinson 1988). Here protected wells were perceived as being little more than a marginal improvement over the traditional open wells, and, given the many alternative uses for their money, on the average families indicated that they would pay less than 0.5 percent of their income for the improvements. On the other hand, in rural communities in the Indian state of Kerala (Singh and Ramasubban 1989) the existing level of service—public taps—was much too low. Many families were prepared to pay high tariffs for a reliable yard tap supply.

This article describes a study undertaken in three rural areas of Brazil. The study addresses three basic questions:

- Are people's responses to willingness-to-pay questions believable?
- How much are people willing to pay for water?
- Is it possible to raise tariffs and increase revenues while protecting the poor?

II. Modeling Water Demand: Specification and Data

Specifying the Model

In rural settings, the principal decision of interest to a water supply planner is the proportion of families that will connect for a given level of service and given prices. Thus what is needed is a model that describes the probability that a particular family will choose to use a new water source.

First it is assumed that a family chooses between two sources (j) based on maximizing two conditional indirect utility functions, the first of which describes the utility gained from using the new source ($j = 1$), and the second the utility derived from use of the current, old water source ($j = 2$). In each case, the utility, U, for a particular family, i, of a particular source depends on time and monetary costs of obtaining water from that source, C_j, the perceived quality of its water, V_j, household income, Y_i, and a set of socioeconomic variables used as proxies for the families' tastes, Z_i. The researcher does not observe all components of utility, so an error term, ϵ_{ij}, is added to the utility function (McFadden 1974).

The utility function for each household is thus:

$$U_{ij} = \alpha_0 + \alpha_1 C_j + \alpha_2 V_j + \alpha_3 Y_i + \alpha_4 Z_i + \epsilon_{ij}$$

The probability that family i will decide to use the new rather than the old source is the probability that the conditional indirect utility function for the new source, U_{i1}, is greater than the conditional indirect utility function for the old source, U_{i2}. Letting $Pr = U_{i1} - U_{i2}$, the probability that family i will connect is the probability that $Pr > 0$. Assuming that the distribution of the resulting error terms is normal, the parameters of Z can be estimated using the probit model (Judge and others 1980).

Generating Data for Estimating the Model

There are two basic procedures for generating data to assess what water-supply services people want and what amount they are willing to pay for these. First consider a situation in which a new water-supply service has been installed and in which each family has decided whether to switch to the new source. For each family information is collected on the choice of source (the dependent variable), the characteristics of the old and new sources, and family characteristics (the independent variables). A discrete choice model (such as the probit or logit) is then used to assess the effects of the independent variables on the probability of connection.

The great attraction of this so-called indirect method is that inferences are based on actual behavior rather than the actions that survey respondents say they would take. For some variables of interest (such as family characteristics) this method works well, because there is typically significant cross-sectional variation in these characteristics. The great drawback is that in cross-sectional studies across a city or region, the most policy-relevant variables, such as connection cost, tariffs, and levels of service, are usually constant across all respondents. Without variation in these variables it is not possible to assess household response to them. In longitudinal studies it is similarly difficult because complex relationships among the "independent" variables can give rise to spurious correlations. For instance, studies have often noted that increases in tariffs have been followed by increases in numbers of connections and per capita consumption. This is not attributable to some perverse price elasticity but rather to the fact that in many developing countries potential demand has been suppressed by supply constraints, and to the fact that it is frequently politically feasible to raise tariffs only after a utility has been able to effect service improvements.

The second, alternative, procedure for assessing what services people want and what they are willing to pay for these involves the simple, obvious, and direct procedure of presenting people with hypothetical options (both in terms of quality of service and prices) and asking them to indicate what choice they would make. Surveys of this sort have widely been considered unreliable "due to the pervasive feeling that interrogated responses by individuals to hypothetical propositions must be, at best, inferior to 'hard' market data or, at worst, off-the-cuff attitudinal indications which might also be expected to reflect efforts by individuals to manipulate the survey to their selfish ends" (Cummings and others 1985, p. 50). In the specific case of rural water supplies, in the late 1970s a World Bank review of water-demand studies using such hypothetical questions concluded that the approach had been shown to be "virtually useless" (Saunders and Warford 1977).

The major, obvious, problem with this method is that biases may arise, for three related reasons. First, individuals may not understand or perceive correctly the characteristics of the good or service being described by the interviewer (hypothetical bias). Second, the respondent may think that he can influence the provision of services in his favor by not answering the questions truthfully (strategic bias). And third, the respondent may give answers which are influenced by his desire to please the interviewer (compliance bias).

Over the last decade, however, primarily in response to the difficult problem of valuing nonmarketed environmental goods, there have been significant conceptual and empirical advances in methodologies for conducting such "contingent valuation" surveys. Despite great initial misgivings about the usefulness of the method, it is now generally acknowledged that the major sources of bias can be addressed. First, where the hypothetical service to be introduced is not well known to the community (seldom a problem with water supplies) information can be provided through pictures, films, and discussions so that the nature of the service is clear. Second, it is possible to assess the magnitude of strategic biases through the use of a variety of techniques, such as choosing settings which would encourage or discourage strategic behavior, and comparing the effects of, say, family characteristics derived from contingent valuation and "indirect" methods. And third, through careful recruitment and training of interviewers, compliance biases can be minimized. As a consequence of these advances, the contingent valuation method has become a widely accepted method for evaluating the benefits of environmental improvements in industrial countries (Cummings and others 1985).

III. A Case Study: Willingness to Pay for Water in Brazil

In 1987 the World Bank initiated a multicountry study of willingness to pay for water. One objective of the study was to assess whether the contingent valuation method was reliable for assessing demand for public goods in developing countries. The empirical studies were designed to assess how the proportion of families using a new system was affected by characteristics of the family and of the old and new water supply systems. The study was also designed to suggest what might constitute an appropriate water supply system both technically and financially in different environmental and socioeconomic settings.

The studies were carried out jointly by a World Bank team and collaborating institutions in Brazil, India, Nigeria, Pakistan, Tanzania, and Zimbabwe. This article describes the Brazil study briefly; preliminary results from other country studies have been presented elsewhere (Robinson 1988; Singh and Ramasubban 1989; Altaf and others 1989; Whittington and others 1990).

Site Selection

Three areas were chosen for study in Brazil: one in the interior of the relatively prosperous, well-watered southern state of Paraná; and two in poor, dry areas of the Northeast, one in northeastern Minas Gerais, the other in Ceará. The study design called for identifying areas where improved services were available but where not all families had chosen to connect (A sites), and others where improved services were not yet available (B sites). The aim was to interview about 200 families at each site.

Summary information on the survey sites is shown in table 1. The A villages already have an improved water source available. In all three cases the water-supply system comprised a piped distribution network, to which households could connect. To encourage households to use the new systems, connections were provided free, with the only charge being a flat monthly tariff. The A1 and A2 designations represent houses that have chosen to install yard taps and

Table 1. *Summary Description of the Community Data Sets, Brazil*

State, region and village	*Hooked up?*	*Level of service*	*Monthly tariff (cruzados)*	*Sample size (households)*	*Bid range (cruzados)*
Ceará (Northeast)					
A1	Yes	Yard tap	41	100	50–200
A2	No	Yard tap	41	100	0–40
B3	—	Not set	Not set	200	0–10 for public taps 15–100 for yard taps
Minas Gerais (Northeast)					
A1	Yes	Yard tap	41	340	50–200
Paraná (South)					
A1	Yes	Yard tap	41	140	50–200
A2	No	Yard tap	41	52	0–40
B1	—	Yard tap	41	100	10–200
B2	—	Yard tap	Not set	100	10–200
B3	—	Not set	Not set	100	0–10 for public taps 15–100 for yard taps

—Not applicable.

Note: A = improved services available; B = improved services not available; A1 = yard taps installed; A2 = chose not to hook up; B1 = yard tap and prevailing prices to be offered; B2 = yard tap offered, price not determined; B3 = neither tap nor tariff system determined. At the time of the surveys, U.S. dollar = 25 cruzados.

Source: World Bank data available upon written request to John Briscoe.

those that have chosen to not hook up, respectively, within the A villages. The B villages do not yet have improved water sources, but B1 villagers will be offered yard taps at the prevailing price in the system, while B2 villagers know that they will get a yard-tap-based system but that the tariff has not yet been determined. For B3 villagers, neither the level of service (yard tap or public tap) nor the tariff structure has yet been determined.

The Survey

For all families information was collected on socioeconomic characteristics including measures of income, assets, employment, education, and family size and structure; and characteristics of the old water source(s), including level of service, distance from the house, reliability, and perceived quality of the supply.

Bidding games were administered to all families. The basic form of the bidding game was to ask: "If you were required to pay X cruzados per month for a connection, would you choose to connect to the system or would you prefer to use the alternative source?" Each family was asked this question for a range of monthly tariffs. Based on experience in industrial countries (Cummings and others 1985), the sequence of the bids was to start at extremes (the lowest or highest value to be asked) and converge inward. Thus, for instance, if the prescribed values were 50, 100, 150, and 200 cruzados, the order would be (for a low starting point): 50, 200, 100, 150.

For the families which had connected at the current charge of 41 cruzados (the A1 households), the bids ranged from 50 to 200 cruzados. For families which had chosen not to connect at 41 cruzados (A2), the bids ranged downward to zero. In the B villages the range extended from 10 to 200 cruzados for yard taps and from 0 to 10 cruzados for public taps. The bidding games are summarized in table 1. Because the Ceará and Minas Gerais families were interviewed after the Paraná families, their prices were deflated to account for the effect of inflation.

Analysis

The probability of connecting to an improved system. Household characteristics are hypothesized to affect both tastes and the opportunity cost of time. It is expected that a family will be more likely to connect if it is relatively well-off and if the family head is relatively well educated, is employed in the formal sector, and owns significant assets. Using cluster analytic techniques, Bussab (1988) showed that the best measure of accumulated assets for the study families was the number of domestic electric appliances that the household owns. Our measure of wealth is a dummy variable equal to 1 if the number of electrical appliances owned by the household was more than one standard deviation above the mean.

In villages where the type and tariff of future systems is already set, B1, households might be expected to overstate their maximum willingness to pay, because they know that this would not affect the type of service or the tariff in their villages, but might think high bids could positively influence the agency to initiate service in their area. Households in B2 and B3 villages, however, might be expected to understate their actual willingness to pay, because they might hope that a low bid would influence the utility to provide service at a relatively low tariff.

Families would be more likely to connect at low than at high tariffs, all other things being equal, and more likely to connect to a high level of service (yard tap) than a low level of service (public tap). Where the distance to the existing source is great, families also are expected to be willing to pay more for a yard tap.

Two wrinkles in the estimation procedures are worth mentioning. The first relates to the fact that in the sample, the proportion of households that did not connect to the water system was larger than their share in the general population in the A villages. To obtain consistent parameter estimates when using nonlinear estimation procedures, such as the probit used here, the estimates take into account the nonrandom sampling (Maddala 1983).

Second, the obvious way of entering the data (eight data points entered for a respondent who gives answers to eight specific bids) introduces correlation among the errors for each household. This procedure gives unbiased parameter estimates, but inflated estimates of the *t*-statistics and therefore of precision. This problem was dealt with through a straightforward procedure which is consistent with the recent "bootstrapping" literature, in which computer time is substituted for analysts' time in calculating test statistics for problems that are intractable from a deductive standpoint. Two types of runs were made. First, the point estimates of the parameters were estimated from a model that used all the data. But to estimate the true standard errors of these estimates, one observation was picked at random from each group of observations for each family, thus reducing the sample to the number of respondents. This procedure was followed ten times; the reported values for the *t*-statistics are based on the average values of the standard errors from these ten runs.

The analysis was further complicated by a loss of the data on distance to the water source for the Ceará families. The following procedure was devised to analyze the effect of distance and to use the full sample to obtain relatively precise estimates of the effects of the other independent variables. First the parameters of the full model were estimated using the Paraná and Minas Gerais data sets (run 1). Then the parameters of the full model were estimated using the same data sets but excluding the "distance to alternative source" variable (run 2). This run showed that all of the coefficients that are significant in the fully specified model are significant in the misspecified model, with the probit coefficients for these variables virtually identical in the two cases. Also, the misspecified model, excluding distance to the alternative source, was estimated for the complete data set for the three regions (run 3). The parameter estimates were consistent with those of the second run.

Because probit coefficients are difficult to interpret, the effects of the right-hand-side variables on the probability of connecting are presented in two other ways. For continuous independent variables, the elasticities are the meaningful measure: the percent changes in the probability of connecting induced by 1 percent changes in the income, price, and distance variables. For discrete independent variables elasticities are not meaningful because small changes in the values are not possible, and so the marginal probabilities are presented: the changes in the probability of connecting when the values of the independent variables are changed from zero to one.

The results for the full sample (run 3) are presented in table 2. In all cases the signs of the parameters are as expected, and in all but two cases the estimates are highly statistically significant. On the basis of the full model, including distance from source but excluding the Ceará data (run 1), the elasticity of the connection choice with respect to the distance of the old source was calculated as 0.03. The estimate was significant at the 90 percent level in a one-tailed test.

What about the magnitude of the effects? One way of thinking about these is first to conceive of the intercept as the probability of hooking up for a (counterfactual) family with an uneducated head and no income, that owns few appliances, has a close current source, can have a yard tap for free, and lives in a village in Ceará with an improved system. From table 2, the probability of such a family connecting to the improved system would be 45 percent. Education would have a large effect: a family identical except that the household head had one to four years of education would have a probability 7 percent higher, and the effect of completing primary education would be to raise the probability by 20 percent. Being employed in the formal sector would raise the probability by 7 percent, and owning a significant number (beyond one standard deviation above the mean) of electrical appliances would increase the probability by 17 percent. If the family lived in a B village the probability of connecting would be 5 percent higher; if the family lived in a B2 or B3 village the probability would be 29 percent (−0.34 + 0.05) lower.

For the continuous variables, elasticities are computed at the sample means. For the average family, the probability of connecting would increase by 15 percent if income were doubled (to about $320 per month) and decrease by 68 percent if the tariff were doubled (to about $7 per month). The probability would increase by 3 percent if distance to the existing source were doubled to about 100 meters (from run 1, not shown in table 2). (The estimated elasticities are, of course, not valid for such large changes in the independent variables. The large numbers, however, give a sense of the magnitudes involved.)

Another way of looking at the same data set is to model the effects of characteristics of the family and the existing source on maximum willingness to pay. Because the range of willingness-to-pay bids was arbitrarily truncated (at zero and 200 cruzados) a modification of the ordinary least squares procedure was used (the tobit procedure; Judge and others 1980). The results for

Table 2. *Determinants of the Probability of Connecting to the Improved System (Full Sample, 1,164 Observations)*

Independent variable	*Probit coefficients*	*Mean value*[a]	*Marginal probability (for discrete variables)*	*Elasticity (for continuous variables)*
Constant	1.17 (8.11)		+0.45	
Family characteristics				
Monthly household income (cruzados)	0.00004 (3.74)	4,336		+0.15
Major appliance ownership	0.44 (4.54)	0.26	+0.17	
Formal sector employment	0.17 (2.13)	0.55	+0.07	
Head's education, 1–4 years	0.18 (2.35)	0.50	+0.07	
Head's education, >4 years	0.53 (2.84)	0.10	+0.20	
Characteristics of new source				
Real price of yard tap (cruzados per month)	−0.01 (15.33)	87		−0.68
Site				
B village	0.13[b] (0.57)	0.42	+0.05	
B2 or B3 village	−0.90 (4.80)	0.33	−0.34	
Paraná state	−0.26 (2.35)	0.41	−0.10	
Minas Gerais state	−0.15[b] (0.84)	0.25	−0.06	

Note: The mean value of the dependent variable, the probability of connecting, is 0.58. T-statistics are in parentheses. All coefficient estimates are statistically significant at the 95 percent level (one-tailed test) except as noted.

a. Proportion of sample except for household income and yard tap price.

b. Significance level is less than 90 percent (one-tailed test).

Source: Authors' calculations, based on World Bank data available upon written request to John Briscoe.

the full sample (excluding the distance to the alternative source) are presented in table 3. As expected, the results are consistent with those of the probit estimations—the signs of the parameters are consistent with a priori expectations, and the estimates that were significant in the connection-probability model are significant in the willingness-to-pay model, with only minor exception in the significance of site characteristics.

Choosing between a yard tap and a public tap. Throughout the developing world increasing attention is being given to recovering part of the costs of rural

Table 3. *Determinants of Willingness to Pay for a Yard Tap*

Independent variable	*Tobit coefficients*	*Mean value*[a]
Constant	89.8 (15.0)	
Family characteristics		
Monthly household income (cruzados)	0.0017 (4.43)	4,462
Major appliance ownership	34.26 (6.65)	0.27
Formal sector employment	12.9 (3.02)	0.56
Head's education, 1–4 years	14.92 (3.31)	0.49
Head's education, >4 years	27.49 (3.64)	0.11
Site		
B village	14.59 (1.68)	0.43
B2 or B3 village	−75.95 (8.71)	0.34
Paraná state	3.67[b] (0.71)	0.40
Minas Gerais state	−2.23[b] (0.37)	0.24

Note: Based on full sample for the three regions, excluding distance to the alternate source (1,082 observations). The mean value of the dependent variable, the willingness to pay, is 104 cruzados per month. T-statistics are in parentheses. All coefficient estimates are statistically significant at the 95 percent level (one-tailed test) except as noted.

a. Proportion of sample except for household income.

b. Significance level is less than 90 percent (one-tailed test).

Source: Authors' calculations, based on World Bank data available upon written request to John Briscoe.

water supply systems from the users. There are, however, legitimate concerns that increased tariffs will force many people (and particularly the poor) to return to alternative, and often polluted, traditional sources. One response has been to suggest that where yard taps are the standard level of service (in much of Latin America), increased tariffs for yard taps might be accompanied by the provision of free water at public taps. Although this proposition offers a partial solution to the equity concern, it raises a concern that the availability of free public taps might act as an incentive for people not to connect to the system and may thus compromise the financial viability of the system.

To address this concern, additional data were collected at those sites in Ceará and Paraná where no decision had been made on either the level of service to be provided or the monthly tariff to be charged (B3 villages). In the bidding games, tariffs for both a public tap and a yard tap were presented to the respondent. The tariff for using the public tap was initially zero and the tariff for the yard tap initially 40 cruzados. Depending on the initial choice made by the respondent, he or she was led through a series of tariff combinations in which the public tap tariff was increased to a maximum of 20 cruzados per month, and the yard tap tariff was increased to 100 cruzados per month. At each price combination, respondents were asked whether they would use their original source, a public tap or a yard tap.

The specification of the choice model is as before, except that now there are three (alternative source, public tap, or yard tap), rather than the original two possibilities (alternative source or yard tap) for the dependent variable. This requires use of an estimation procedure—the multinomial logit (Judge and others 1980)—which is conceptually similar to the probit model, but which allows for more than two possibilities for the dependent variable.

It is expected that (as in the probit model) the probability of using a yard tap would increase with income, whereas the current source and public tap are probably inferior goods. Both formal sector employment and higher education increase the opportunity cost of collecting water from outside of the house, increasing the probability of choosing a yard tap and reducing the probability of using the current source. With regard to the public tap, however, the higher opportunity cost of collecting water from a public tap would cause the coefficient to be negative, but increased knowledge of the benefits of using treated water would lead to a positive coefficient. The net effect is difficult to predict a priori. One would expect standard own- and cross-price effects for the tap tariffs. It is also expected that families in Ceará (compared with those in Paraná) would be more likely, all else being equal, to use both public taps and yard taps given the scarcity of water in Ceará.

The results of the multinomial logit estimations are derived in three forms: the log odds ratios, the marginal probabilities, and the elasticities. As is the case for all regression procedures with qualitative dependent variables, the log odds ratios are difficult to interpret directly. A more meaningful presentation is of the marginal probabilities for the discrete independent variables and elasticities for the continuous dependent variables.

Table 4 shows that the effects of income, price, and site are generally large and significant, and the direction of the effect is as predicted. Overall the correspondence between expected and actual signs is strong. Nineteen of twenty-one of the signs of the parameters are as expected: the two exceptions are signs we were not confident in predicting, namely the negative effect of one to four years of education on choosing a yard tap, and the positive effect of more than four years of education on choosing the current source.

The implications of the results for rural water supply policy in Brazil. Consider the revenue effects of increasing the tariff charged for a yard tap. As expected, this would cause some families to switch to public taps and some to current sources. Table 4 shows that the direct price elasticity of the private tap at the mean is −0.47. That is, a 10 percent rise in the price of a yard tap

Table 4. *Determinants of the Probability of Using a Particular Source of Water*

	Marginal probabilities (for discrete variables) and elasticities (for continuous variables)		
Independent variable	*Current source*	*Public tap*	*Yard tap*
Constant	−0.09	+0.20*	+0.30**
	(1.21)	(1.43)	(2.1)
Family characteristics			
Monthly household income[a]	−0.42*	−0.57**	+0.24**
	(1.44)	(1.80)	(2.67)
Major appliance ownership	−0.14	−0.04	+0.18
	(1.03)	(0.41)	(1.26)
Formal sector employment	−0.03	−0.06	+0.09
	(0.24)	(0.79)	(0.31)
Head's education, 1–4 years	+0.03	+0.03	−0.06
	(0.44)	(1.06)	(1.07)
Head's education, >4 years	+0.03	−0.03	+0.01
	(0.07)	(0.05)	(0.13)
Characteristics of new source			
Real price of yard tap[a]	+1.01**	+0.81	−0.47**
	(1.94)	(0.91)	(2.33)
Real price of public tap[a]	+0.11	−0.36**	+0.04
	(0.74)	(1.75)	(0.81)
Site			
Ceará	−0.39**	+0.11**	+0.28**
	(5.77)	(1.91)	(3.64)

**indicates statistical significance at the 95 percent level or above (one-tailed test).
*indicates statistical significance at the 90 percent level or above (one-tailed test).
Note: T-statistics are in parentheses.
a. This is a continuous variable; therefore, the reported parameter value is an elasticity.
Source: Authors' calculations, based on World Bank data available upon written request to John Briscoe.

would induce a 5 percent decrease in the use of yard taps. Thus increasing tariffs above the mean (about 70 cruzados for these bidding games) would raise revenues, because the increased revenues from those staying connected would more than offset the revenues lost from those disconnecting. As expected, increasing the price of the public taps would reduce the number of households using them, although the decrease should be slight. The associated positive effect on revenues would not, however, be material to public tap policy, the goal of which is to provide a basic level of water supply for the poor, not to generate revenues.

To get a feel for the magnitude of likely responses, it is informative to present these results graphically. Figure 1 shows how little water-use patterns in Paraná change as the tariff for a public tap is changed. But yard tap demand is much more price-responsive: as yard tap tariffs increase, connection probabilities decline, and those who disconnect tend to revert to the alternative source rather than to using a public tap (see figure 2).

In dry Ceará, at current tariffs the proportion using yard taps is high, but again water-use patterns are little affected by the public tap charge (figure 3). Because current water sources are less satisfactory in Ceará than in Paraná, as tariffs for yard taps increase a substantial proportion of the population would switch and use the free public taps (figure 4).

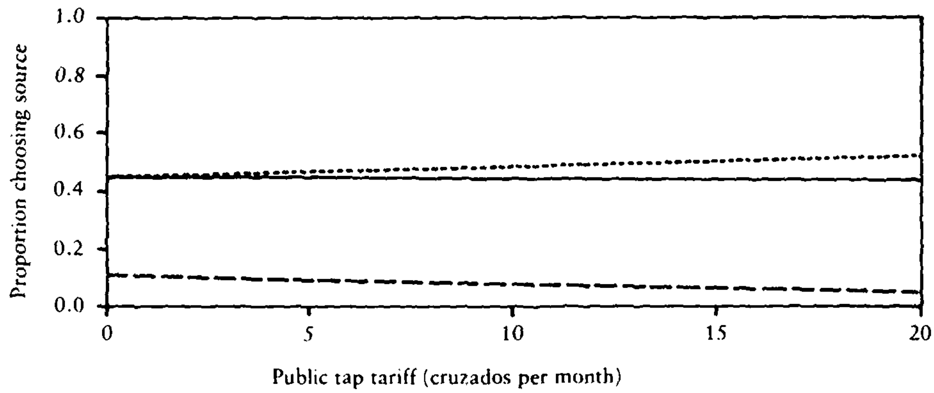
Implications: Credibility, Willingness to Pay, and Protecting the Poor

Credibility of the responses. What evidence is available to ascertain the extent of bias in the responses to the bidding games? There are several perspectives on this question. First, the field team comprised five highly experienced field researchers from the Brazilian Institute of Public Opinion and Statistics (IBOPE). They were initially skeptical of the notion of the bidding games but, after a few days of field testing, were convinced not only that the logic of the procedure was understood by respondents but that the respondents gave serious and thoughtful answers. The interviewers were confident that there was no hypothetical bias (because the product was well known to all respondents). The interviewers did, however, feel that there was some strategic behavior, particularly in the villages in which no decision had yet been made on whether a system was to be installed, or what level of service was to be provided or tariff charged (the B3 sites). The lower values of the willingness-to-pay parameters for the B2 and B3 villages relative to otherwise comparable communities are consistent with these impressions.

Second, the B villages were chosen so that there were different implicit incentives for strategic behavior. In villages in which the villagers were certain that a system was to be installed, and knew that the level of service and tariff were predetermined, B1, there appeared to be little incentive for strategic behavior. The marginal probability parameter on the "B village" variable in table 2 is not significantly different from zero, indicating that there was no discernible strategic behavior in these villages. In villages in which decisions had not yet been made on tariffs, B2, and level of service and tariffs, B3, there were substantially stronger a priori reasons to expect that respondents would underestimate their willingness to pay for a yard tap. The large and significant negative coefficient and marginal probability of connecting for these villages support this (table 2). A resident in a B2 or B3 village would indicate a maximum willingness to pay of 60 cruzados less on average than a comparable resident in other villages (table 3). Presumably the intention of such strategic behavior is to signal to decisionmakers that a lower tariff must be set for their region or they will not participate.

From one perspective, this strategic bias is large (because average maximum willingness to pay is about 100 cruzados). Even in the B2 and B3 sites, however, where there is evidence of considerable strategic behavior, the average

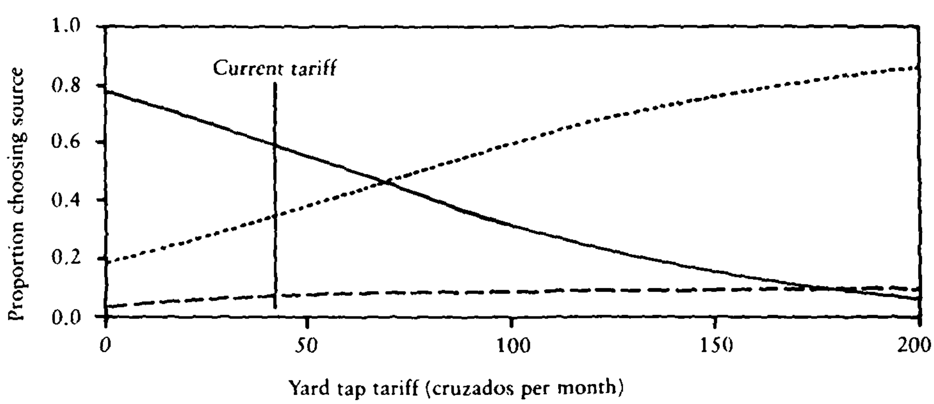
Figure 1. *Effect of Public Tap Tariff on Choice of Water Source, Paraná*



Key: ...... current source; — — public tap; —— yard tap.

Note: Results for villages in which neither the type nor tariff of the prospective water system has been determined.

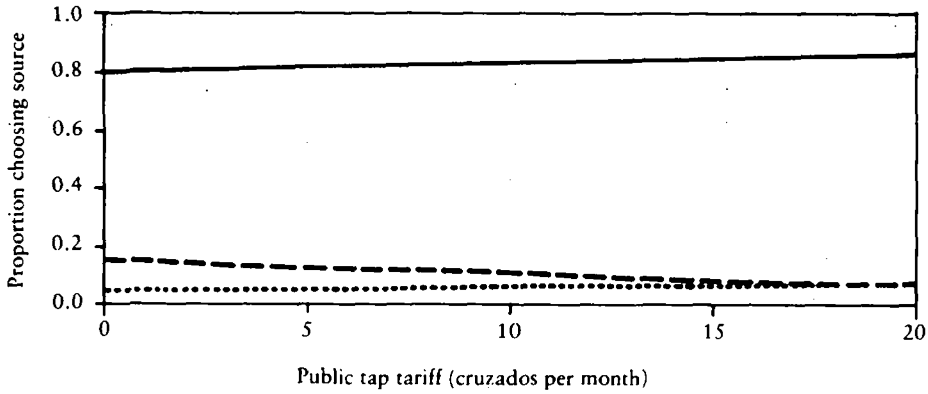
Figure 2. *Effect of Yard Tap Tariff on Choice of Water Source, Paraná*



Key: ...... current source; — — public tap; —— yard tap.

Note: Results for villages in which neither the type nor tariff of the prospective water system has been determined.

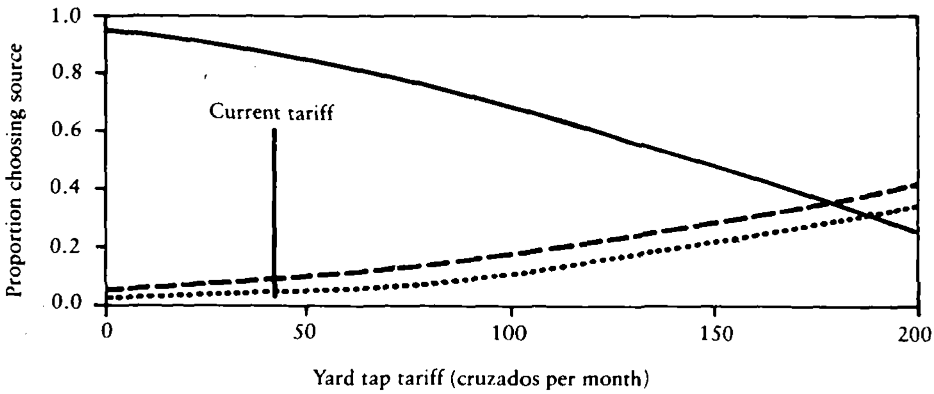
Figure 3. *Effect of Public Tap Tariff on Choice of Water Source, Ceará*



Key: ...... current source; — — public tap; —— yard tap.

Note: Results for villages in which neither the type nor tariff of the prospective water system has been determined.

Figure 4. *Effect of Yard Tap Tariff on Choice of Water Source, Ceará*



Key: ...... current source; — — public tap; —— yard tap.

Note: Results for villages in which neither the type nor tariff of the prospective water system has been determined.

maximum willingness to pay was 74 and 56 cruzados, respectively. From the perspective of policy, the effect of strategic bias in this particular case is largely of academic interest, because the tariffs that would be justified on the basis of these "lower bound" estimates would still represent large increases over existing tariffs of only 41 cruzados.

Third, the effects of virtually all variables were as expected on theoretical grounds. The effects of the economic variables (income, assets, tariffs for yard taps, and tariffs for public taps) were uniformly strong and sensible.

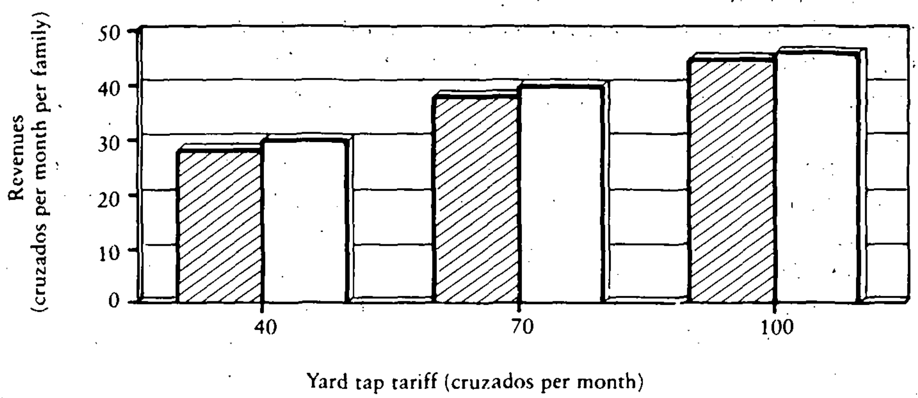
What services do people want and for what are they willing to pay? For this sample, the average stated maximum willingness to pay for a yard tap was about 100 cruzados, 2.5 times the monthly tariff at the time of the survey, and about 2.3 percent of average reported family income for the sample. Because 35 percent of the sample appeared to behave strategically, this should correctly be regarded as a "lower bound" estimate of the average willingness to pay. The conclusion is that a majority of people are prepared to pay much higher tariffs than those currently being charged for yard taps in rural Brazil.

As expected, willingness to pay for a yard tap is positively affected by income, assets, education, and formal sector occupation. It does not follow, however, that people in the poorer northeast Minas Gerais and Ceará are willing to pay less than relatively well-off villagers in the southeast Paraná. This is because the alternative water source in Paraná is reliable dug wells close to most homes, which is much more attractive than the alternative in Ceará—unreliable surface sources relatively far from most houses.

The response to increased tariffs is different in the two regions. The own-price elasticity of demand for a yard tap connection is substantial in Paraná (figure 2) where reliable dug wells are generally readily available. Despite the fact that families in Ceará are much poorer, the impact of yard tap tariffs is less in Ceará (figure 4) than in Paraná, again presumably because alternative sources are much less satisfactory in Ceará. In relatively wealthy, well-watered Paraná, families choose to use existing wells, with very few choosing to use public taps. In relatively poor and relatively dry Ceará, at high yard tap tariffs substantial numbers of families choose to use both public taps and alternative sources.

Is it possible to have a financially viable tariff while protecting the poor? Households in Paraná and Ceará were asked both about yard taps and public taps. The results suggest that households do not see these as close substitutes. Because prices for the two systems were varied, there was less movement between those two choices than there was back to the original choice. Moreover, families with more income and assets were more likely to choose a yard tap over a public tap. Assuming that the marginal cost of public taps is negligible, they offer a straightforward method to reach households that are unwilling or unable to pay for a yard tap. Given the low cross-price

Figure 5. *Total Revenues under Different Tariffs for Yard Taps and Public Taps*



Key: [hatched] public tap tariff = 0; [blank] public tap tariff = 20.

elasticity between yard and public taps (table 4), and assuming that the water utility puts the public taps nearer to areas of poorer households, relatively few households would switch from paying for a yard tap to using a free public tap.

What about the financial viability of a water utility under the alternative tariff structures? Figure 5 also shows that even when tariffs are 2.5 times current levels (which is the average maximum willingness to pay), total revenues rise as tariffs increase.

But what about equity concerns? First, as implied by the positive income elasticity of demand for connections to yard taps (tables 2 and 3), it is the relatively better-off families in these rural communities who are choosing to install yard taps and who are, therefore, the principal beneficiaries of the subsidies implicit in this service. Second, as shown by the negative income elasticity of demand for use of public taps (table 4), it is the poor who would be the principal beneficiaries of free public taps. It would appear possible, then, to improve the equity of these rural water supply systems by effectively cross-subsidizing: by charging high tariffs for the yard taps used mainly by the better-off and providing free public taps that are used mainly by the poor. But is it possible to do this without threatening the financial viability of the rural water system?

Figure 5 shows that the price charged for using water from a public tap has little effect on the revenues of the utility. Because of the need to protect the poor and because it is difficult to devise mechanisms for collecting payments for water use from public taps, the clear conclusion is that water should be provided free from public taps.

IV. Conclusions

The principal methodological question addressed by the study can be answered affirmatively. Well-designed and carefully administered surveys of actual and hypothetical water-use practices can provide consistent, sensible, and believable information on willingness to pay for improved water supply services.

The empirical results show that tariffs for yard taps can be increased very substantially before significant numbers of households would choose not to connect to an improved system. Major increases in tariffs for yard taps would both improve the financial viability of rural water supply schemes and reduce the subsidies that the better-off receive through heavily subsidized rates. The study also shows that the poor can be protected by providing free water at public taps, without jeopardizing the financial viability of the scheme.

It should also be emphasized that these empirical results are specific to Brazil. Results of a similar study in Nigeria (Whittington and others 1990) are significantly different. The final publications of this multicountry study of water demand and pricing will document the methodological and policy implications from all six of the country studies.

References

Altaf, M. A., H. Jamal, J. L. Liu, V. K. Smith, and D. Whittington. 1989. "Who Connects to Public Water Systems in Developing Countries: A Case Study of the Punjab, Pakistan." World Bank Infrastructure and Urban Development Department Discussion Paper. Washington, D.C. Processed.

Briscoe, John, and David de Ferranti. 1988. *Water for Rural Communities: Helping People Help Themselves*. Washington, D.C.: World Bank,

Bussab, W. 1988. "Disposicão a pagar por água nas areas rurais." University of São Paulo. São Paulo, Brazil. Processed.

Churchill, Anthony. 1987. *Rural Water Supply and Sanitation: Time for a Change*. World Bank Discussion Paper 18. Washington, D.C.

Cummings, R. G., D. S. Brookshire, and W. D. Schulze. 1985. *Experimental Methods for Assessing Environmental Benefits: Volume 1A: Valuing Environmental Goods: A State of the Art Assessment of the Contingent Valuation Method*. Office of Policy Analysis, Planning, and Evaluation, U.S. Environmental Protection Agency. Washington, D.C.

Hubbell, L. K. 1977. "The Residential Demand for Water and Sewerage Services in Developing Countries: A Case Study in Nairobi." Urban and Regional Report 77-14. World Bank Development Economics Department. Washington, D.C. Processed.

Inter-American Development Bank. 1985a. "Chile: Programs de Agua Potable Rural: Project Report." Washington, D.C.

———. 1985b. "El Salvador: Rural Water Supply Program: Project Report." Washington, D.C.