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ANALYSIS

Willingness to pay for improved water service in Manaus, Amazonas, Brazil

James F. Casey [a], James R. Kahn [a,b,*], Alexandre Rivas [a,b]

[a] *Washington and Lee University, Lexington, VA, USA*
[b] *Universidade Federal do Amazonas, Brazil*

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Abstract

The 1.5 million residents of the city of Manaus form the epicenter for economic activity and development in the Amazon Basin. The current water treatment facilities were built when there were a mere 100,000 people living here. The fifteen-fold increase in population has made access to water a major public health concern. Families that can afford to buy bottled water do and those that can not are susceptible to water-borne disease and illness at an ever-increasing rate. In order to determine how much citizens are willing to pay for universal access to water service in the home, the University of Amazonas, Center for Environmental Sciences has conducted a survey of over 1600 residents, collecting information on current water needs, health concerns, household socioeconomic characteristics, and, from a contingent valuation (CV) experiment, how much they would pay for access to improve water service in the home. This paper makes use of the 1479 observations from four elicitation formats; (1) open-ended, (2) open-ended with a "pre-qualifying" statement, (3) descending bid dichotomous choice, and (4) ascending bid dichotomous choice. Results suggest that residents are willing to pay (WTP) more than R$12 (US$6.12) per month.

1. Introduction

"The urban water supply situation in many developing countries is bad and getting worse. Many households do not have private connections and have no choice but to purchase water from vendors or queue to collect water from public taps or wells. Many households that tap into a piped distribution system may share the resource with neighbors and have water for only a few hours per day" (Whittington, 2002 p.2). The situation described in Whittington's (2002) opening paragraph describes the current situation in Manaus.

As with many other growing cities in the developing world, access to a reliable water source is rapidly becoming a major public health concern. Incidence of water-borne disease is on the rise and the amount of time and money from private, mostly poor, residences going into collecting water is an inefficient use of already scarce resources. Faced with such constraints

* Corresponding author. Environmental Studies Program, Washington and Lee University, Lexington, VA 24450, USA. Tel.: +1 540 458 8036.
E-mail address: kahnj@wlu.edu (J.R. Kahn).

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municipalities are exploring ways to provide universal access to water in urban areas. As with many other developing countries, Brazil is considering private alternatives for the delivery of water services. In order to help with the development of such public works projects it is important to know how much individual households are willing and able to pay for services. It is important to note that, in general, water prices are established based on supply costs. Thus, the focus of this paper is the determination of the value of universal access to improved in-home water service through a willingness-to-pay approach.

Similar to other recent empirical studies in developing countries (Raje et al., 2002; Whittington et al., 2002), our research indicates a strong preference for improved water services. Estimates of willingness to pay are in the $10 to $14 Reais (US$5.10 to US$7.14)[1] per month range and are significantly higher than current water expenses per household. The rest of this paper is structured as follows. Section 2 provides background information for the current conditions in Manaus. Section 3 develops the theoretical model of household demand for water services used in this paper. Section 4 discusses the sampling strategy and questionnaire design. Section 5 discusses the empirical findings and Section 6 concludes the paper.

2. Background

Manaus, the capital city of Amazonas state, is situated at the confluence of the Rio Negro and Rio Solimões, where they form the Amazon River. Manaus came to its economic prominence during the two rubber booms (turn of the 19/20th century and World War II). Its strategic location and prominent role in extractive industry made it a major city in the Amazon region, but its population was well-below one hundred thousand people for most of the 20th century.

The 1960s saw a change in economic orientation, as the Federal Government created a set of economic incentives to give manufacturing (at that point, mostly assembly) a reason to locate in Manaus. The manufacturing activity has taken-off in the last 15 years, with a huge presence of high-tech industry, electronics, and conventional industry. Much of the activity is now manufacturing (as opposed to assembly) and the city is a source of high-quality jobs in comparison to much of the region.

As a result of these economic activities, there has been a large influx of population into Manaus, increasing its population more than ten-fold in the last 3 decades. Unfortunately, much of the inflow has been people looking for jobs and there are an order of magnitude more people who want these jobs than there are jobs available. Many of the people who arrive are from South or Northeast Brazil who had left the poverty of their regions to try farming in Amazonia. When they failed as farmers, they moved to Manaus, rather than returning to their original home.

The reader may find it strange that this paper looks at the supply of water in a city that has 20% of the world's freshwater flowing past it. However, the problem of safe and reliable drinking water has been created by the immigration and the city's reaction to immigration.

The impact of this migration on water supply is quite interesting, as most of the families moved into favelas (squatter-slums) without services such as sewage, water and electricity. Although the families could illegally tap into water and electricity lines, sewage was discharged directly into the small creeks that flow through the city, with many of the slums and the creeks that drain them located upstream of the municipal water intake on the Rio Negro. Despite the massive flow of the Rio Negro, this made municipal water somewhat unsafe, particularly if quality control of the treatment plant was not adequately maintained. Additionally, even though the new water company has changed most of the primary supply pipes, secondary, and particularly tertiary supply pipes are old and leaking, leading to sources of contamination down the pipes of the treatment plant.

There are many options for improving drinking water quality, including building and upgrading treatment facilities, reliance on groundwater in the immediate vicinity, and reliance on groundwater from an area 100 km north of Manaus (Presidente Figureido) that has ample supplies of both groundwater and artesian water. As part of a general movement towards privatization of services in Brazil, a foreign water company bought the water supply rights for Manaus. It is now in the process of evaluating service potential and commissioned the survey upon which this study was based.

[1] An exchange rate of 1.96 Brazilian Reis to 1 US dollar is used throughout the paper.

Of course there are issues with the privatization of water services. Historically, the delivery of water services has been seen as a public service. Recently there have been growing calls to consider allowing a regulated private sector to deliver water services (Galiani et al., 2002). There are even a number of case studies demonstrating that newly privatized water firms are more efficient, invest in more infrastructure, and provide better quality services (Galiani et al., 2002; Hazzin, 2001). Another obstacle to privatization has been the public perception that privatization hurts the poor. However, Galiani et al. (2002) find evidence that privatization in Argentina has had a progressive effect in reducing health inequality. Privatization in Argentina has led to a 24% reduction in child mortality in certain municipalities with high levels of poverty.

3. A simple model for household water demand

Manaus residents are typical consumers in that they maximize utility subject to constraints. The demand for water can be viewed as any other good or service and therefore modeled within the utility maximization framework or alternatively within the expenditure minimization model.

$$E(W,X) \tag{1}$$

$$s.t. U = U(W,X). \tag{2}$$

Faced with expenditures for both water services (W) and a composite good (X) subject to the utility constraint, the consumer will attempt to minimize the following expenditure function:

$$E^* = E(P_w, P_x, U) \tag{3}$$

However, since universal water service is being offered as a take-it or leave-it proposition it makes sense to think of this as a restricted demand problem where the consumer does not observe P_w and choose W, but rather is offered W and can choose to pay for it or not. Therefore, P_w is replaced with W and the expenditure function takes the following form

$$E^* = E(W, P_x, U). \tag{4}$$

In this restricted case, the WTP for water, or improved water services is simply the difference between two expenditure functions with $W_1 > W_0$ and the compensating surplus welfare estimate can be derived from this difference.

$$CS(W_0, W_1) = E(P_x, W_0, U_0) - E(P_x, W_1, U_0) \tag{5}$$

This estimate of compensating surplus is a measure of the willingness to pay for universal water services in the home. It is the amount that each household is willing to give up and still remain at the previous utility level before the change.

We can think of this WTP for universal service as a function of not only the cost of service, but also a host of socioeconomic, demographic, and attitudinal characteristics of the household, which can be represented by d in the expenditure function.

$$CS(W_0, W_1) = E(P_x, W_0, U_0; d) - E(P_x, W_1, U_0; d) \tag{6}$$

4. The data

In order to derive actual estimates of WTP a survey was administered. Six low-income communities in the eastern area of Manaus were chosen to participate in the survey and, within these communities, households were randomly chosen for in-person interviews. A total of 1625 questionnaires were administered from the 18th of January through the 5th of February 2001.[2] The survey is broken into four sections providing a rich set of data for covariate analyses. The first collects information pertaining to household demographics. Part two asks questions about health issues in the household. Part three elicits information concerning household infrastructure and services available to the household and section four is the actual contingent valuation experiment, which contains four different elicitation formats. Format 1 uses an open-ended CV with a preliminary (augmenting) paragraph (AOE). Format 2 uses an open-ended CV without any introductory paragraph (OE). The third and fourth formats use the bidding game approach with format three start-

[2] The survey was designed based on previous socioeconomic research performed in the study area. The questionnaire was pretested through face-to-face interviews and implemented in a similar fashion. Only 1479 of the original 1625 are used in the analysis.

ing at R$145 and descending (DB) and format four the ascending bidding method (AB) starting at R$6.

AOE — I am going to ask you a question about how you value water services. Your answer will NOT determine how much you will have to pay. The dollar amount will only be used to value water services. How much would you be willing to pay per month to receive water in your house available 24 hours a day?

OE — How much would you be willing to pay per month to receive water in your house available 24 hours a day?

DB — Would you be willing to pay R$145 per month to receive water in your house available 24 hours a day? —If YES the game ends, if NO then the amount is reduced to R$87, R$49, R$22, R$14, R$6, and R$0.

AB — Would you be willing to pay R$6 per month to receive water in your house available 24 hours a day? —If NO the game ends, if YES the amount is increased to R$14, R$22, R$49, R$87, and R$145.

As with any contingent valuation study there are always issues of potential bias. However, it has also been shown in the literature that "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" (Briscoe et al., 1990, p.133). Additionally, Griffin et al. (1995) find results from contingent valuation data in India consistent with actual willingness to pay. One of the advantages of this data set is that we can formally test for differences across the four formats to see if one or any of them is providing significantly different estimates of WTP.

5. Empirical findings

5.1. Socioeconomic profile and current services and infrastructure

One thousand four hundred and seventy-nine household interviews are used in this analysis. The households were divided evenly between the four CV formats. Of all the respondents, almost 70% live in two communities, Jorge Texiera A and Communidade Sharp, with the remaining 30% living in the other four communities. All six communities tend to be working class or low-income communities.

Fifty-four percent of survey respondents are the head of the household and the average respondent is 34 years old (Table 1). Seventy percent of these individuals were born in urban areas with almost 36% born in the city of Manaus. On average the respondent has lived in Manaus for 21 years, but only in the present neighborhood for 5 years. Eighty-one percent report to have worked in the past, but only 43% report currently being employed outside the home. Mean income is R$443 per month, which is slightly more than two times the minimum wage. Almost 90% of the respondents own their home and 88% of these people have paid off the loan for the home entirely. Most homeowners purchased their homes (85%), but almost 7% received their home as part of a government program.

The average home has three rooms and one bath and almost 43% are made of brick blocks (Table 2). As opposed to wood construction, brick blocks are preferred due to the high humidity and rainfall in the region, but they are more expensive. Eighty percent of the homes have a full kitchen and 21% have washtubs for clothing in the home.

Only 0.2% of households surveyed currently have a water meter and the maximum that any household pays for water service is R$19 (US$9.69) per month (Table 3). Oddly, with only 0.2% of respondents having metered water, only 11% of households report buying water. Many households have private wells or the use of a private well. Households purchasing water outside the home have average expenditures of R$1.32 (US$0.67) per month with the highest reporting R$97 (US$49) per month. A reported 60% of homeowners

Table 1
Demographics (D)

Variable	Mean	SD	Min	Max
Age	34.4	12.7	10	91
Househead	.534	0.49	0	1
Born in Manaus	.358	0.47	0	1
Urban	.689	0.46	0	1
Years in Manaus	21.5	14	0	74
Years in neighborhood	4.9	3.4	0	56
Working	.43	0.49	0	1
Homeowner	.896	0.3	0	1
Income	443.25	713	0	20,351

Table 2
Residence (R)

Variable	Mean	SD	Min	Max
Purchased	.846	0.36	0	1
Government	.066	0.25	0	1
Paid in full	.884	0.32	0	1
Number of rooms	3.07	1.8	1	14
Brick home	.429	0.49	0	1
Number of baths	1.05	0.37	0	11
Kitchen	.798	0.4	0	1
Sink	.48	0.4	0	1
Washcloths	.944	0.23	0	1
Washtub	.213	0.4	0	1

have a private well. Ninety-nine percent of the households have electricity with almost all of these hooked up by Manaus Energy (the city's energy supply company). The average monthly electricity bill is R$18.84 (US$9.61) with a reported high of R$ 460 (US$234).

One of the main issues associated with water service improvement is public health. Diarrhea alone accounts for almost 15% of all child deaths worldwide (Galiani et al., 2002). A review of 144 studies by Esrey et al. (1991) indicated that improvements in one or more components of water supply and sanitation substantially reduce rates of morbidity, diarrhea, hookworm infection and other water-related disease. Again, Galiani et al. (2002) find that child mortality fell by approximately 5% to 7% in areas where water services were improved through privatization.

Although not as severe as in other mega cities in developing countries, Manaus still has its water-related illness (Table 4). Among those surveyed, 63% reported having a case of dengue fever in the past year. Almost 11% reported at least one case of severe diarrhea and eight percent reported having to deal with intestinal worms. There were very few reported cases of malaria, hepatitis or cholera.

Table 3
Services (S)

Variable	Mean	SD	Min	Max
Metered water	.002	0.05	0	1
Monthly bill	.038	0.77	0	19
Buy water	.112	0.32	0	1
Amount paid	1.32	5.5	0	97
Electricity	.998	0.04	0	1
Manaus energy	.85	0.36	0	1
Monthly energy bill	18.84	24	0	460

Table 4
Health (H)

Variable	Mean	SD	Min	Max
Dengue	.628	0.48	0	1
Hepatitis	.006	0.08	0	1
Worms	.08	0.27	0	1
Diarrhea	.108	0.31	0	1
Malaria	.051	0.22	0	1
Cholera	.001	0.03	0	1

5.2. Willingness to pay

Rather than jump directly to the regression analysis, it is useful to look first at some non-parametric analysis of willingness to pay. For the open-ended response formats, less than 5% of the respondents were willing to pay more than R$30. As the price falls from R$30 to R$10 we go from 5% to almost 67% of the respondents included. The next 25% are included from R$10 to R$0, which leaves about 8% of the respondents having zero willingness to pay.

For the bidding game formats, less than 6% of the respondents in the descending bid (DB) format reached zero and only 4% of the respondents in the ascending bid (AB) format said NO to R$6. Approximately 10% of the responses in the (DB) format were R$49 and higher as compared to 4% in the (AB). As we move from R$49 to R$22 the percentages increase to 60 and 53 and the next step to R$6 brings the numbers to 94% and 96% for the (AB) and (DB) formats, respectively.

In order to determine if there was anything special or different about the 79 households, who expressed zero WTP, we conducted some cross-tabulation exercises. There are no major differences between households who are willing to pay something and those that are not willing to pay anything. However, there are three statistically significant differences between these 79 households and the others: (1) they are older, (2) they are more likely to have received their homes

Table 5
Non-parametric WTP estimates

	AOE	OE	DBDC	ABDC	Total
Number of respondents	376	382	365	356	1479
Mean WTP	12.94	12.45	16.93	13.04	13.82
SD	9.8	9.32	14.65	9.2	11.1

Table 6

Explanatory variables	Variable definition	Expected sign
Age	Age of respondent	−
Househead	Head of the household (1=yes)	+
Yhood	Years living in the present neighborhood	+
Income	Monthly household income	+
Work	The respondent is presently employed (1=yes)	+
Homeowner	The home is owned, not a rental (1=yes)	+
Brick	The house is made of brick (1=yes)	+
Paywater	Monthly expenses for water outside the home	+
Energybill	Monthly electricity bill	+
Cholera	Anyone in the house has had cholera in the past year (1=yes)	+
Hepatitis	Anyone in the house has had hepatitis in the past year (1=yes)	+

through a government program, and (3) they are less likely to be purchasing water outside the home.

Based on the direct responses to the valuation questions, we can see in Table 5 that households are willing to pay between R$12 (US$6.12) and R$17 (US$8.67) per month. The open-ended and augmented open-ended formats display nearly identical mean WTP and standard deviations around the respective means. It is the descending bid dichotomous choice format that provides the highest WTP and the highest variance around the mean. One of the benefits of this type of analysis is that it helps to hypothesize about expected results from the regression analysis. It should come as no surprise that the coefficient on the dummy variable for the (DB) format would have a positive sign and be of statistical significance.

Table 7
Regression results

Variable		
Age	−.06***	−.05***
Househead	.83*	.87**
Yhood	.23***	.12**
Income	−.23	
Work	1.42***	1.41***
Homeowner	1.88***	1.52***
Brick	.66	.37
Paywater	.20***	.21***
Energybill	.07***	.07***
Cholera	5.05	4.7
Hepatitis	.68	1.9
Format a	−.12	.003
Format c	1.96***	1.5***
Format d	.71	.40
Constant	8.84***	8.3***
N	972	1463
F statistics	12.30***	15.86***

***=.01, **=.05, and *=.10.

Table 8
Willingness-to-pay estimates

	Mean WTP	SD	Lower	Upper
Full I	11.91	2.97	5.19	6.63
Full	11.81	2.59	17.83	16.99

In order to gain more insight into WTP and its covariates, we conducted multivariate regression analysis with similar specifications to Whittington et al. (2002) and Briscoe et al. (1990). Microeconomic theory suggests that WTP should vary across individuals with different demographic characteristics (D), and different residence characteristics (R), different levels of current services (S), and different health situations (H). Therefore, the following equation was estimated using OLS.

$$\mathrm{WTP}_i = \alpha_0 + \beta(D_i) + \delta(R_i) + \lambda(S_i) + \sigma(H_i) + \varepsilon. \quad (7)$$

Table 6, below, summarizes the variables used in the regression along with our hypotheses about the expected relationship between WTP and the covariates.

Initially, 10 models were estimated—one for each of the four formats and a full model with dummy variables controlling for elicitation format—and with two specifications for each format (income included and excluded). Table 7, below, presents the results of the two full models.[3]

The first model makes use of 972 useable observations. The second model drops the income variable to make use of more observations and has 1463 observation points.[4] Both models are highly significant according to standard F-tests. Since we detected het-

[3] Although we present and discuss only the results of the full models here, each of the partitioned models provides similar information—with the exception of statistical significance for several covariates.

[4] It is common for people NOT to report their income and in this case almost a third of the respondents chose not to give their income.

Table 9
Willingness-to-pay estimates

	Mean WTP	SD
Full I	11.91	2.97
Full	11.81	2.59
AOE I	10.81	2.87
AOE	11.15	2.79
OE I	11.07	3.21
OE	11.19	3.08
DB I	13.76	2.98
DB	13.48	2.17
AB I	11.75	2.27
AB	11.75	1.24

eroskedasticity, we are using the sandwich estimator of variance[5] in place of the traditional calculation of variance, which actually makes it more difficult to not reject the null hypothesis of an individual's coefficient being equal to zero.

The only variable that did not have the expected sign was *income*. Theory suggests that income should be positively related to WTP; acting as a demand shifter. Upon first examination, our estimate of a negative impact on WTP is counterintuitive. However, it should be noted that the coefficient is NOT statistically different from zero and to think that income might not have an effect on demand because the actual price for improved water service is a small percentage of an individual's income is not counter to conventional wisdom.

Although it is difficult to generalize based on the results of one study, each of the positively related explanatory variables tells a potentially interesting story about willingness to pay for water services. The *Househead* and *Yhood* variables may be telling a story about investment in the home over time and perhaps about investment in the community and a commitment to improving the quality of life. *Work* may be reflecting a permanent income story, whereby those who are currently employed are more certain about the flow of income in both the short and long run. *Homeowner* may reflect a security aspect to willingness to pay where the resident knows they will be staying in the home or if they decide to move the piped water service will have increased the value of the home. *Energybill* may be a proxy for economic activity in the home and it may also tell a story about services in general, whereby households with greater energy demands may also have greater water demands and are more familiar and trusting of the services provided. Also, residents who are currently paying more for water, *Paywater*, are willing to pay more for improved water service in the home. This is almost certainly an opportunity cost story. Finally, each of our health variables has the expected positive relationship to WTP, but neither is estimated with precision.

Although the information pertaining to the determinants of willingness to pay are interesting, it remains the primary purpose of this paper to estimate an actual dollar amount for WTP. Solving both equations provides mean estimates of R$11.91 (US$6.08) and R$11.81 (US$6.02), respectively. Notice that these estimates are lower than the actual stated WTP of individuals (Table 5). In addition to these two estimates, we also present the results from the partitioned regressions from each of the four formats with and without the income variable (Tables 8 and 9).[6]

The lowest estimate comes from the augmented open-ended (AOE) format (10.81) and the highest is from the descending bid (DB) format (13.76). If we take the lower bound estimate from the AOE model and the upper bound estimate from the DB model, we obtain a range of WTP estimates from R$5.07 (US$2.59) to R$19.72 (US$10.06).

6. Conclusion

The results of this study provide the first evidence that households in Manaus, the economic hub of the Amazon, are willing to pay considerably more for improved water service than they are paying for current service. On average households in these six low-income and working class communities in Manaus are willing to pay more than R$11 or US$5.61 per month. This amounts to more than US$72 per year per household, which is approximately two-and-one-half percent of a household's annual income.[7] These results are consistent with previous work in rural Brazil (Briscoe et al., 1990), urban India (Griffin et al., 1995; Raje et al., 2002) and urban Nepal (Whittington et al., 2002). Our results show that the quality of life of people in these, and similar, communities in Manaus can be

[5] For a full explanation see Hamilton, L.C., 2002. Statistics with Stata. Belmont, CA: Duxbury.

[6] Individual regression models are available upon request from the authors.

[7] The Brazilian pay period is based on 13 months.

significantly improved by improving the safety and reliability of drinking water supply. Although there have been insufficient valuation studies to compare the willingness to pay for improvements in drinking water with the WTP for improvements in other public services, one can make a convincing case that the municipal government of Manaus should undertake an upgrade of water services, even if it means raising costs to consumers.

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References

Briscoe, J., Furtado de Castro, P., Griffen, C., North, J., Olsen, O., 1990. Toward equitable and sustainable rural water supplies: a contingent valuation study in Brazil. The World Bank Economic Review 4 (2), 115–134.

Esrey, S.A., Potash, J.B., Roberts, L., Shiff, C., 1991. Effects of improved water supply and sanitation on ascariasis, diarrhoea, dracunculiasis, hookworm infection, schistosomiasis, and trachoma. Bulletin of the World Health Organization 69 (5), 609–621.

Galiani, Sebastian, Gertler, Paul, Schargrodsky, Ernesto, 2002. Water for Life: The Impact of the Privatization of Water Services on Child Mortality.

Griffin, C., Briscoe, J., Singh, B., Ramasubban, R., Bhatia, R., 1995. Contingent valuation and actual behavior: predicting connections to new water systems in the State of Kerala, India. The World Bank Economic Review 9 (3), 373–393.

Hamilton, L.C., 2002. Statistics with Stata. Brooks and Cole/Thompson Learning, Mason, Ohio.

Hazzin, L.S., 2001. Private sector participation in water supply and sanitation: realizing social and environmental objectives in México D.F. In: Nick, J., Libby, W. (Eds.), Private Firms and Public Waters: Realizing Social and Environmental Objectives in Developing Countries. Edward Elgar, Cheltenham, UK.

Raje, R.V., Dhobe, P.S., Deshpande, A.W., 2002. Consumer's willingness to pay more for municipal supplied water: a case study. Ecological Economics 42, 391–400.

Whittington, Dale, Pattanayak, S.K., Yang, J., Bal Kumar, K.C., 2002. Household demand for improved piped water services: evidence from Kathmandu, Nepal. Water Policy 4, 531–556.

Whittington, Dale, 2002. Municipal water pricing and tariff design: a reform agenda for cities in developing countries. Issue brief 02-29, Resources for the Future, Washington, D.C.