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WATER AND SANITATION FOR ALL: PARTNERSHIPS AND INNOVATIONS

Household choice of water supply systems

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STUDIES OF PIPE-water demand in developing countries have traditionally analysed household connection decisions to the pipe water system. These studies have yielded useful insights on the value of water and savings in time (e.g., Altaf et al., 1992; Asthana, 1995, 1996, 1997; Singh et al., 1993). Empirical observations, in some places, however, reveal that often households augment piped water supply with alternate sources. Households invest in coping strategies in the form of alternative supplies and storage facilities. Because these strategies have important implications, there is a need to develop an understanding of households' water demand that goes beyond connection decisions.

On the basis of theoretical advances made by Ben-Akiva, and Lerman, (1985) and their application by Madanat, and Humplick (1993), this paper presents a model system of household water supply choices. The model accounts for the possibility that the households may use different supply systems for different uses of water. Moreover, the relation between the households' choice of water supply and their connection decisions is explicitly modelled.

The model

Choosing a source of water is an economic decision that involves choice among discrete alternatives. Accordingly, in this case a discrete choice probabilistic model will be appropriate. Since the utility is not directly observable, an indirect utility function will be used.

Conditional indirect utility function of household h:

$$U_{ih} = U_{ih}(X_{ih}, Z_{ih}) \quad (1)$$

where *i* indicates the water source;

h denotes the household;
X is a vector source characteristics; and
Z is a vector of household characteristics.

According to random utility theory, such unobservable or unmeasurable influences are assumed to be captured in a random term, which for operational purposes is usually assumed to be added to the systematic term:

$$U_{ih} = V_{ih} + e_{ih} \quad (2)$$

where V is the systematic term and *e* is the random term.

Let the variable y_{jh} indicate household h's choice decision on source j such that:

$$y_{jh} = \begin{cases} 1 \text{ if } V_{jh} + e_{jh} > V_{ih} + e_{ih} \\ \text{for } i, j = 1,...J \text{ and } i \neq j \\ 0 \text{ otherwise} \end{cases} \quad (3)$$

The expected value of y_{jh} is thus:

$$E(y_{jh}) = P(y_{jh} = 1) \quad (4)$$
$$= P(U_{jh} > U_{ih}) \quad (5)$$
$$= P(V_{jh} + e_{jh} > V_{ih} + e_{ih}) \quad (6)$$

The independent variables in vector X_{jh} vary across sources. The standard statistical method of dealing with them is a logit model. The independent variables in vector Z_{jh} do not vary across sources. The standard approach for them is the polychotomous model.

Our data structure will include both types of independent variables. However, since source characteristics do not influence household characteristics and vice versa, the household's utility function may be assumed to be additive:

$$V_{ih} = BX_{ih} + a_i Z_h \quad (7)$$

The following conditional logit model can be used to deal with the data structure which includes both groups of independent variables:

$$P_h(j) = \frac{e^{BX_{jh} + \alpha_j Z_h}}{\sum_{i=1}^{J} e^{BX_{ih} + \alpha_i Z_h}} \quad (8)$$

The estimation procedure for this conditional logit model is essentially the same as for a standard logit model because the household-specific vector Z_h can be transformed into a choice-specific vector. Therefore, the maximum likelihood method will give a consistent estimate of the parameter vector B.

The equation being used allows a ready interpretation of the selection probabilities in terms of the relative representative utilities of alternatives and is amenable to computation.

As the contingent valuation method suffers from various biases, viz. (1) Hypothetical bias due to the hypothetical nature of the question; (2) Strategic bias because the respondent may perceive an opportunity to manipulate the outcome; (3) Compliance bias because the respondent attempts to anticipate responses the interviewer wants; and (4) Starting point bias with bids being influenced by interviewer's suggestions; the revealed preference method has been used in this research. The dependent variable is the choice variable.

Data

The area of our case study covers the peri-urban areas of the city of Bhopal in Central India. These area are densely populated but poorly planned. Many of these slums are squatter settlements but with no chance of eviction.

A two-staged stratified random sample of households was used with observations taken from 250 units.

In this paper, our interest is restricted to the households in the pipe connection area. These households either have private connections or collect water from public stand post. The deficiency of the piped water supply is manifested by the fact that only 19 per cent of households in the pipe connection area use this source exclusively to fulfil their daily needs. Most households with private connections augment this system by storage of water (large tank and small motor) or supplement it by water from dug wells and surface source (ponds). Households collecting water from public stand posts also supplement the supply from other sources.

Model specification and regression results

Maximum likelihood estimation of the conditional logit model can be shown under very general conditions to provide estimators that are asymptotically efficient and normally distributed. Examples suggest that the approximation is reasonably good, even in small samples. When independent variables are highly correlated, their matrix becomes singular and the results explode. The problem of selection of independent variables in logit models is more acute than in linear regression. The selection has to be on the basis of economic theory and intuition rather than a computer dictated algorithm where forward or backward selection depends on Wald statistic or change in likelihood ratio. A large number of regressions with different variables were tried to reach the final results.

A binary logit model of pipe network connection decision and several multinomial logit models of water supply source choice were estimated.

In the source choice models, the universal choice set consists of private pipe water, public stand post, hand pump, dug well and surface water. All these alternatives except one (in-house pipe connection) are assumed available to every household in that segment. The availability of in-house pipe water to a household is given by the connection decision. In other words, the availability of in-house pipe water is treated as a household characteristic in the source choice model. For those households with a pipe connection, the choice set is the same as the universal choice set; for the others, the choice set includes one alternative less.

Whereas water is required for many purposes, the primary focus was on drinking and bathing because these activities represent different uses of water. For drinking, the most important attribute is water quality, whereas for bathing, reliability and pressure are critical attributes.

The two source choice models included two types of explanatory variables: household characteristics and source characteristics. The first category included indicators of income, education, household size as well as presence of storage tank in the house. It is expected that households with higher income and education will favour pipe water as such households have the ability to pay for the higher cost, as well as a higher appreciation for the benefits of using better quality water. Households which have invested in storage facilities are expected to be more likely to use pipe water than households which do not have tanks, as storage mitigates the reliability and pressure problems associated with private house connections.

Estimation results are summarised in tables 1 to 3. Table 1 shows the estimation results for the multinomial

Table 1. Multinomial logit model of water source choice for bathing

Explanatory Variables	Estimated coefficients*				
	$V_{\text{public PW}}$	V_{HP}	$V_{\text{dug well}}$	V_{surface}	$V_{\text{private PW}}$
Alternative-specific constant	-6.01 (-8.62)	-4.80 (-5.86)	-1.86 (-2.64)	-1.56 (-2.83)	...
PW pressure level (inverse)	...	...	...	...	-1.07 (-4.77)
No. of persons per household	...	...	...	...	0.09 (1.99)
Educational level	...	...	...	...	0.30 (4.53)
Storage dummy	...	...	...	...	1.49 (2.99)

* Standard errors in parenthesis.

Table 2. Multinomial logit model of water source choice for drinking

Explanatory Variables	Estimated coefficients*				
	$V_{\text{public PW}}$	V_{HP}	$V_{\text{dug well}}$	V_{surface}	$V_{\text{private PW}}$
Alternative-specific constant	-6.01	-4.80	-1.86	-1.56	...
	(-8.62)	(-5.86)	(-2.64)	(-2.83)	
Hand pump dummy	...	5.09	...	...	...
		((3.10)			
Source quality perception	4.12	3.03	2.93	...	4.03
	(6.88)	(5.02)	(5.11)		(6.01)
Educational level	0.10	0.09	...	...	0.10
	(2.11)	(2.02)			(2.11)
Improvement in quality of pipe water	...	...	...	...	2.01
					(1.99)

* Standard errors in parenthesis.

logit model for water supply source choice for bathing. Each of the five columns represents the systematic utility for one of the alternatives. The first row shows the values of the alternative-specific constants. In a multinomial choice model, the maximum number of alternative-specific constants that can be identified will be one less than the number of alternatives. Each constant represents the utility of that alternative relative to the base alternative (the alternative for which no constant is specified) controlling for everything else. The estimated values of the four constants, which correspond to the first four alternatives, are all negative. This indicates that, had everything else been equal, pipe water from an in-house connection is the preferred alternative for bathing. According to the magnitude of these coefficients, the least preferred alternative for bathing is public pipe water. Since these alternative-specific constants reflect unobserved factors such as convenience, the need for privacy etc., it can be seen that their relative magnitudes are intuitively correct.

Large households seem to prefer private connections. The reason could be that as in many peri-urban areas of the third world, private pipe water connections are unmetered. The monthly charge is the same irrespective of the quantity of water used.

Income was found to be strongly correlated with educational level. Moreover, female educational level was found to be strongly correlated with the male educational level. of these variables, best results were obtained by choosing the female literacy level in the household as a variable. Households with literate females seem to have a higher consciousness of hygiene and need a more reliable supply. The overall fit is satisfactory.

In table 2, the results of water supply source choice model for drinking are shown. The alternative-specific constants show that piped water from an in-house connection is the most preferred alternative for drinking, controlling for other factors.

While hand pumps are the main source of safe water in rural areas, hand pumps in urban areas often have faecal pollution. Yet, due to reliability, many hand pumps are in operation in areas covered by piped water system. Hand pump dummy actually represents the data as per the last water quality test. As expected, it has a positive effect on the utility of ground water extracted by hand pumps.

The next row represents the effect of perception of the highest quality of water source by the households. Four dummy variables are included - one for each source, except for hand pump. Each dummy has a value of 1 if that source was judged to have the highest quality of water and zero otherwise. The four variables show a strong positive effect, indicating that perceptions of quality are important determinants of the choice of water supply source for drinking purposes. Next it can be seen that higher the educational level of the household, the

Table 3. Logit model of pipe connection

Explanatory Variables	Estimated Coefficients*
Constant	1.89
	(1.90)
Difference in recurring costas a proportion of household income	-18.99
	(-2.89)
Maximum expected utility of bathing usage (includes laundry)	0.50
	(2.60)
Maximum expected utility of drinking usage (includes cooking)	0.25
	(1.99)

* Standard errors in parenthesis.

more likelihood of using piped water and hand pump water for drinking.

Finally, a variable measures the effect of the change in the quality of the piped water supply since connection was started. It can be seen that the households having experienced an improvement in piped water quality are more likely to use it for drinking than those which experienced either no change or a decrease in quality.

Table 3 shows the estimation results of binary logit model of the connection decision.

The specification for this model the difference in recurring cost between in-house piped water and the other sources available to the household. Since the price of other sources is zero, this variable is actually the monthly pipe water charge divided by monthly household income. As expected, it has a negative coefficient: the more expensive the in-house pipe connection, the less likely is house to connect.

The last two parameters in table 3 represent the effect of the maximum expected utilities of the water supply source choice for the different uses on the decision to connect. These are feedback from the lower-level models, which account for the effect of the water supply source choices for the different uses on the decision to connect. The connection decision seems to be strongly influenced by household expectation or experience with alternative water sources. From the estimation results, it can be seen that the parameters of the maximum expected utility are from each of these models all have estimates between 0 and 1, which is consistent with the theory of multidimensional logit models.

Conclusion

Safe water has long been recognised as a basic need (e.g., ILO, 1976). While delineating policies for achievement of universal coverage by the year 2000, the New Delhi Declaration called for "some for all, rather than more for some". Coming, as it did, at a time when neo-classical counter-revolution was in ascendance, it is somewhat surprising that an egalitarian declaration, achieved a broad consensus at the Global Consultations. This approach was also approved by the U.N. General Assembly.

This policy advice has resulted in a 'minimum unsatisfactory virtually free service to all' approach.

This study reveals that perception of health benefits by the people is significant and they are prepared to spend significantly higher amount of money than that charged by the municipal authorities for piped water supply.

Due to lack of clear thinking relating to demand and user charges, a perverse tariff system exists in most third world cities. In almost all poor countries, there is an element of subsidy in urban water supply, that goes mainly, albeit unintentionally, to the rich (Briscoe, 1992).

There is a need to reconsider the policy of "some for all, rather than more for some" called for by the New Delhi Declaration and adopted by the U.N. General Assembly as "strategy for the 1990's". Rather than trying to provide a free or heavily subsidised minimum-service-to-all system, the policy makers need to consider an improved service to all and higher level of service to those who are willing to pay more.

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