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Calculating the Value of Time Spent Collecting Water: Some Estimates for Ukunda, Kenya

DALE WHITTINGTON
University of North Carolina at Chapel Hill and the World Bank, Washington, DC
XINMING MU
Asian Development Bank, Manila
and
ROBERT ROCHE*
World Bank, Abidjan

Summary. — This article presents two procedures for estimating the value of time spent hauling water in developing countries. Both approaches are used to derive estimates of the value of time for households in Ukunda, Kenya. The results indicate that households in this village place a surprisingly high value on the time they spend collecting water, a value approximately equivalent to the wage rate for unskilled labor. These findings suggest that the economic benefits of improved water services in developing countries may be much greater than is commonly realized.

1. INTRODUCTION

Many women in developing countries spend a significant portion of their day hauling water from sources to their homes. One of the principal benefits of improved water delivery systems such as yard taps, handpumps, and standposts is that the time women spend carrying water is reduced (Churchill *et al.*, 1987). The time saved by not having to haul water from more distant sources may be put to many other productive uses, such as child care, wage employment, agricultural labor, or food preparation (Curtis, 1986; Cairncross and Cliff, 1987).

Because different water system improvements result in different time savings, the choice of water service level involves a tradeoff between increased costs and the benefits from reduced time spent hauling water by members of the community (typically women). For example, yard taps or house connections reduce the time spent collecting water the most, but they are also the most expensive service option. Handpumps and public fountains are often cheap in terms of capital and operating and maintenance costs, but water must still be carried from the source to the home. More handpumps or public fountains in a village can reduce the average travel time from houses to sources, but this also increases total capital costs. The choice of which technology is most appropriate for a given community may thus be heavily influenced by the value of time which households assign to the time savings.

There is, however, little empirical evidence concerning the value people actually place on the time they spend collecting water. In its water project appraisal methodology, the Inter-

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American Development Bank assumes that time savings should be valued at 50% of the market wage rate for unskilled labor in the local economy, but there is no empirical justification for this assumption. Estimates of the value of time obtained from studies of people's travel mode choices in developed countries indicate that people typically value travel time savings at less than their market wage rate (Bruzelius, 1979; Yucel, 1975), but whether these kind of findings have any relevance for time savings resulting from improved water service in villages in developing countries is not known.[1]

The purpose of this paper is to present two approaches for estimating the value of time spent collecting water and to illustrate their application in a specific location, Ukunda, Kenya. The second section of the paper summarizes the application of discrete choice theory to the problem of a household choosing among different water sources, and develops a methodology for estimating a household's value of time spent hauling water. In the third section, we briefly describe the area where the case study was conducted and the field procedures which were utilized to collect the data for the analysis. The fourth section presents the results of this first approach to calculating the value of time spent collecting water, and then presents an estimate of the value of time based on a conditional multinomial logit model estimated with the same data set. In the fifth and final section we discuss the implications of the analysis.

2. THE APPLICATION OF DISCRETE CHOICE THEORY TO WATER SOURCE DECISIONS IN VILLAGES IN DEVELOPING COUNTRIES[2]

Traditional microeconomic theory postulates that a consumer chooses quantities of goods and services in order to maximize his or her utility, subject to a budget constraint. The solution of this maximization problem yields first-order conditions which can be solved for demand functions which describe the individual's decision regarding the quantity of a good to consume as a function of given prices and his or her income. The quantity of the good demanded is typically assumed to be continuous.

This framework for understanding consumer behavior needs to be modified when a consumer faces choices that are discrete rather than continuous. For example, a household in a village typically chooses from among a limited number of water sources. In rural areas, households typically do not use more than one source for the same purpose. After a source is chosen, the quantity of water used is a continuous variable, but the initial choice of the water source is discrete.[3]

Discrete choice theory offers an alternative theoretical framework which is still based on the concept that utility maximization is the household's criterion for determining the set of preferred consequences. However, instead of deriving a demand function from the first-order conditions of the consumer's utility maximization problem, analysts using discrete choice theory work directly with the utility function. The conceptual framework suggested by discrete choice theory is as follows:
Among J exclusive alternatives (e.g., water sources), household h will choose alternative j if and only if

$$U_{jh} \geq U_{ih} \qquad \text{for } j, i \in J \text{ and } i \neq j \qquad (1)$$

where U_{jh} and U_{ih} are "well-behaved" indirect utility functions conditioned on the choice decision.

The utility derived from using a water source may be expressed as a function of the attributes of the source — such as quality, reliability, and price — and households' tastes, which are usually measured by socioeconomic characteristics of the household such as income, education, demographic structure, and religion (Lancaster, 1966). Conceptually, these indirect utility functions transform the attractiveness of alternative i (including its cash price) to household h to a scalar which the decision maker attempts to maximize through his or her choice.

To illustrate, let us assume a village has three kinds of water sources: kiosks,[4] open wells, and vendors who deliver water to the house. Since each source is different in terms of price, collection time, and taste, the utility that a household derives from using one source will be different from the utility derived from using the others. We define the indirect utility function in terms of the following attributes of the water sources: (i) price of water, P; (ii) collection time per liter — travel time for the household to the source and return, plus queue and fill time at the source, COL; and (iii) taste, T.[5] Each of the three water source alternatives has different values of these attributes so that the utility of each of the three water sources (assuming it is chosen) is given by:

$$U_v = U(P_v, COL_v, T_v) \qquad (2)$$
[Utility of using a vendor]

$$U_k = U(P_k, COL_k, T_k) \qquad (3)$$
[Utility of using a kiosk]

$$U_w = U(P_w, COL_w, T_w) \quad (4)$$
[Utility of using an open well]

The utility U_i, $(i = v,k,w)$, is clearly conditional on source i being chosen (Hanemann, 1984). For simplicity, we assume an additive form of the indirect utility function so that:

$$U_v = B_1P_v + B_2COL_v + B_3T_v \quad (5)$$
[Utility of using a vendor]

$$U_k = B_1P_k + B_2COL_k + B_3T_k \quad (6)$$
[Utility of using a kiosk]

$$U_w = B_1P_w + B_2COL_w + B_3T_w \quad (7)$$
[Utility of using an open well]

The Bs are parameter values of the indirect utility functions representing the household's preferences. We expect B_1 and B_2 to be negative because higher prices and higher collection times reduce the utility a household derives from a source. B_3 should be positive because better taste improves the utility derived from a source.

For purposes of the calculations presented in this section of the paper, however, we ignore the influence of taste, and assume that the household's choice of source is based solely on collection time and cash price. Dividing the indirect utility functions by B_1, we obtain the household's utility per unit of water:

$$U_v/B_1 = P_v + (B_2/B_1)COL_v \quad (8)$$

$$U_k/B_1 = P_k + (B_2/B_1)COL_k \quad (9)$$

$$U_w/B_1 = P_w + (B_2/B_1)COL_w \quad (10)$$

The coefficient (B_2/B_1) is simply the value of time spent carrying water.

We now assume that the alternative with the highest utility will be chosen, which here means selecting the source with the lowest total price per liter (including collection costs). Assume that there is no charge for water from the open wells so that $P_w = 0$, and the collection time per liter associated with using a vendor (COL_v) is zero.[6]

(a) *Case 1 — Household chooses a kiosk*

If household h chooses a kiosk instead of water vendors or an open well, this implies that:

$$U_k > U_v$$

$$\text{or } P_k + (B_2/B_1)_hCOL_{kh} < P_v \quad (11)$$

and

$$U_k > U_w$$

$$\text{or } P_k + (B_2/B_1)_hCOL_{kh} < (B_2/B_1)_hCOL_{wh}.^7 \quad (12)$$

These two inequalities provide an upper and lower bound on the value of time $(B_2/B_1)_h$ for household h as long as $COL_{wh} > COL_{kh}$. The upper bound on the value of time for a household h choosing a kiosk is:

$$(B_2/B_1)_h < (P_v - P_k)/COL_{kh} \quad (13)$$

and the lower bound is:

$$(B_2/B_1)_h > P_k/(COL_{wh} - COL_{kh}) \quad (14)$$

If the term $(COL_{wh} - COL_{kh})$ is negative, this implies that the collection time per liter of the kiosk is greater than for the open well. In this case, the open well is clearly the dominant solution because of the assumption that taste does not affect source choice. In the context of this framework, it would be irrational for the household to choose the kiosk.

(b) *Case 2 — Household chooses a vendor*

If household h selects a vendor, this revealed preference approach yields two lower bounds on the value of time spent hauling water:

$$P_v < P_k + (B_2/B_1)_hCOL_{kh}$$

$$\text{or } (B_2/B_1)_h > (P_v - P_k)/COL_{kh} \quad (15)$$

and

$$P_v < (B_2/B_1)_hCOL_{wh}$$

$$\text{or } (B_2/B_1)_h > P_v/COL_{wh} \quad (16)$$

If the household's value of time is less than the higher of these two lower bounds, it would make sense to switch to either the kiosk or open well. Vended water would be too expensive in terms of the time saved.

(c) *Case 3 — Household chooses an open well*

If household h selects the open well, the procedure yields two upper bounds on the value of time:

$$(B_2/B_1)_hCOL_{wh} < P_v \quad (17)$$

$$(B_2/B_1)_h < P_v/COL_{wh} \quad (18)$$

and

$$(B_2/B_1)_hCOL_{wh} < P_k + (B_2/B_1)_hCOL_{kh} \quad (19)$$

$$(B_2/B_1)_h < P_k/(COL_{wh} - COL_{kh}) \quad (20)$$

If the household's value of time is greater than the lower of these two upper bounds, it would make sense to switch to either the kiosk or the vendor.[8] Table 1 summarizes the formulas for estimating the value of time obtained from these inequalities.

Table 1. *Estimates of the value of time obtained from the revealed preference inequalities*

Source chosen by household	Value of time* Lower bound	Upper bound
(a) Kiosk	$P_k/(COL_w - COL_k)$	$(P_v - P_k)/COL_k$
(b) Vendor	(1) $(P_v - P_k)/COL_k$ (2) P_v/COL_w	
(c) Open well		(1) P_v/COL_w (2) $P_k/(COL_w - COL_k)$

*P_v = price of water from a vendor.
P_k = price of water from a kiosk.
COL_k = collection time per liter for water obtained from a kiosk.
COL_w = collection time per liter for water obtained from an open well.

3. DESCRIPTION OF THE STUDY AREA[9]

Ukunda is a large village or small town of about 5,000 people located 40 kilometers south of Mombasa, Kenya. The economy of Ukunda is heavily influenced by its proximity to the luxury hotels on Kenya's South Coast. Most people either work in agriculture or in tourist-related activities. Over 90% of the Kenyans living along the South Coast are Muslim, although the percentage in Ukunda is somewhat less due to substantial in-migration by individuals from many parts of Kenya in search of employment in the tourist industry.[10] In 1986, per capita income was approximately US$350 per year.

Residents of Ukunda have numerous water sources available in the village. A pipeline built to serve the beach hotels runs through Ukunda. There are only about 15 private connections in Ukunda; the vast majority of people obtain water by purchasing it from water kiosks which are connected to the pipeline serving the hotels and are run by licensed operators, or from water vendors who buy water from the kiosks and deliver it to the household. The vendors carry water in 20-liter plastic jerricans which they transport by large carts or by bicycles. Most of the carts carry 10 jerricans; a full load weighs 200 kilograms. Almost anywhere in Ukunda a person can simply step out of his or her house and hail a vendor.

In addition to the kiosks and vendors, there are six open wells and five handpumps scattered around the village. The depth of the wells ranges from quite shallow to as much as 30 meters, and most provide water year around. Wells are typically private and paid for by wealthier members of the village, but anyone in the community is free to use them. The handpumps in the village were provided by various donors.

In the summer of 1986, staff of the African Medical Research Foundation (AMREF) carried out interviews with 69 randomly selected households in a part of southeastern Ukunda where households have access to several nearby water sources. This area of Ukunda was selected because households have several alternative water sources and the decision as to which one to choose is not at all obvious. Numerous vendors work in this area. There are two kiosks and two open wells, but no handpumps in the study area. Each household is assumed to have three basic choices for its water source: (i) a vendor, who would charge 1.5 Kenyan shillings (ks) per 20 liters (US$0.10); (ii) the nearest kiosk, which would charge 0.15 ks per 20 liters; and (iii) the nearest open well, at no charge.[11] In our sample, 43 households chose a kiosk (62%), 17 chose vendors (25%), and nine chose open wells (13%).

At the time of the field work, the market wage for unskilled labor in Ukunda was about US$0.25 per hour. Wage rates are somewhat higher in the peak tourist season (December–February). Agricultural activities were underway at the time of the survey, but it was not a period of peak demand for agricultural labor.

The household questionnaire consisted of three parts. The first dealt with basic demographic, occupational, and educational data for the family members. The second part consisted of questions on perceptions of the water quality of different sources, the average number of times family members went to the chosen source each day, and the amount of water collected.[12] The third part of the interview dealt with questions about family income, such as livestock and agricultural production and wage employment. In addition, the enumerators collected data on the distance and travel time to each alternative source from each household in the sample by walking from the house to each source. Data were also collected on queue times through observations of each kiosk and open well.

All of the data required for the calculation of the inequalities presented in Section 2 are thus available: price of water charged by the vendor, price charged by the kiosks, collection time per liter for *each* household for each alternative water source, and each household's source choice decision. Moreover, households in the study area generally obtained their water from only one source, and thus this important assumption of the methodology is valid for this village. In other settings, individuals may bathe or do their laundry at a different source than they obtain drinking and cooking water, but in Ukunda surface supplies for bathing and laundry were not readily available.

4. RESULTS OF THE ANALYSIS

(a) *Estimates of the value of time based on the revealed preference approach*

Tables 2–4 present the results of the revealed preference calculations outlined in Section 2 for each of the three groups of households: (i) those households that chose kiosks; (ii) those households that chose vendors; and (iii) those households that chose open wells. The first and second columns in each table indicate the collection times per trip for each household for the well and kiosk, respectively (in minutes). The third and fourth columns in Tables 2 and 3 present the bounds on the value of time spent carrying water (in US$ per hour) based on the calculation of the inequalities developed in the presentation of this revealed preference approach. The estimates of the collection time per liter for the well and kiosk assume 20 liters are collected by each household each trip.[13]

Consider first the results for households which chose kiosks (Table 2). The calculations for four of the 43 households in this group yield inconsistent answers with respect to the upper and lower bounds, and these households were eliminated from Table 2.[14] The upper bounds on the value of time for the other 39 households are presented in the third column. All are greater than the market wage rate of US$0.25, and all but two are less than US$1.00 per hour (mean = US$0.64). The lower bounds on the value of time presented in the fourth column are much less than the values for the upper bounds, and thus do not create a "tight" range for the value of time. Column 5 in Table 2 presents the mid-point of the range between the lower and upper bounds on the value of time for each household. The mean value of these mid-points is US$0.38 per hour (median = US$0.33). Figure 1 presents a frequency distribution of these mid-point estimates of the value of time of households using kiosks. As shown, the estimated values of time do not vary widely (standard deviation = US$0.11). The vast majority fall between US$0.20 and US$0.50 per hour.

Table 3 presents two lower bounds on the value of time for the 17 households which chose vendors (columns 3 and 4). Column 5 presents the maximum of the two lower bounds. Figure 2 presents the frequency distribution of these lower bound estimates on the value of time of households using vendors. The mean of the lower bounds on the value of time presented in column 5 is US$0.57 per hour, more than twice the market wage for unskilled labor.

These data suggest that families in Ukunda which purchase water from vendors implicitly place a surprisingly high value on the time spent collecting water. Households which purchased water from vendors were spending about 8% of their income on water, which is consistent with findings from other countries regarding the percentage of income which people will pay water vendors (Fass, 1988; Linn, 1983; Whittington, Lauria, and Mu, 1989).

The results of the inequality calculations for the nine households which chose open wells are presented in Table 4. In five of the nine cases, the collection time per liter for the kiosk is greater than for the open well, and thus the open well is clearly the preferred alternative, assuming water quality does not affect source choice. The remaining four cases are not a large enough sample upon which to base any conclusions. The fact that these nine households did not choose a vendor does provide upper bounds on their value of time (Table 4, column 3), but these values are quite high (mean of US$0.53) and do not provide much insight into the value of time for households choosing open wells.

The results from these revealed preference calculations for households choosing vendors and kiosks appear consistent with respect to the average incomes of households using vendors and kiosks. For example, the estimated average annual income of households in the sample using vendors was US$2,000. Assuming an average of 1.5 working adults per household and an average work week of 50 hours per adult, the household's

Table 2. *Estimates of the value of time spent hauling water for households choosing kiosks (US$)*

1	2	3	4	5
Time required to collect water from Wells (in min)	Kiosks (in min)	Upper bound estimate on value of time $P_k/(COL_w - COL_k)$	Lower bound estimate on value of time $(P_v - P_k)/COL_k$	Mid-point of interval
22.98	5.50	0.92	0.03	0.48
22.56	7.40	0.68	0.04	0.36
21.10	6.00	0.84	0.04	0.44
20.98	6.60	0.76	0.04	0.68
20.80	3.80	1.33	0.03	0.68
19.86	12.30	0.41	0.07	0.24
18.87	14.50	0.35	0.13	0.24
18.80	14.00	0.36	0.12	0.24
18.80	7.00	0.72	0.05	0.39
18.44	11.30	0.45	0.08	0.27
17.88	6.00	0.84	0.05	0.45
17.80	8.10	0.62	0.06	0.34
17.58	10.80	0.47	0.08	0.27
16.71	13.40	0.36	0.17	0.27
16.70	10.20	0.49	0.09	0.29
16.68	12.30	0.41	0.13	0.27
16.68	12.30	0.41	0.13	0.27
15.81	10.70	0.47	0.11	0.29
15.59	7.40	0.68	0.07	0.38
15.03	9.70	0.52	0.11	0.32
14.65	6.00	0.84	0.06	0.45
14.20	7.70	0.65	0.09	0.37
14.14	7.00	0.72	0.08	0.40
13.83	3.30	1.49	0.05	0.77
13.58	7.60	0.66	0.09	0.38
13.56	9.30	0.54	0.13	0.34
13.53	9.70	0.52	0.15	0.34
13.51	10.20	0.49	0.17	0.33
13.49	10.70	0.47	0.20	0.34
13.06	7.10	0.71	0.09	0.40
12.93	7.60	0.66	0.11	0.39
12.79	6.82	0.74	0.09	0.42
12.72	6.10	0.83	0.08	0.45
12.20	9.30	0.54	0.19	0.37
12.04	9.70	0.52	0.24	0.38
12.02	10.20	0.49	0.31	0.40
11.56	8.90	0.57	0.21	0.39
11.43	6.00	0.84	0.10	0.47
11.39	10.20	0.49	0.47	0.48
Average value of time:		0.64	0.12	0.38
Standard deviation:		0.24	0.08	0.11
Median value:		0.52	0.09	0.33

annual labor supply would be about 3,600 hours. This would imply an average imputed wage rate of US$0.56 per hour. Given the rough nature of these approximations, this is surprisingly close to US$0.57 per hour, the lower bound estimate of the value of time spent collecting water derived from the revealed preference calculations.

The average annual income of households using kiosks was US$1,250. Again assuming an average annual household labor supply of 3,600 hours, the average imputed wage rate for households using kiosks would be US$0.35 per hour. The estimate of the value of time spent collecting water based on the mean of the mid-points of the upper and lower bounds — US$0.38 — is again very close to the average imputed wage rate.

Table 3. *Estimates of the value of time spent hauling water for households choosing vendors (US$)*

1	2	3	4	5
Time required to collect water from Wells (in min)	Kiosks (in min)	Lower bound estimate on value of time $(P_v - P_k)/COL_k$	Lower bound estimate on value of time P_v/COL_w	Maximum of columns 3 & 4
29.72	11.33	0.45	0.19	0.45
21.11	13.95	0.36	0.27	0.36
16.81	7.52	0.67	0.33	0.67
15.73	9.64	0.52	0.36	0.52
15.73	11.75	0.43	0.36	0.43
14.40	3.50	1.45	0.39	1.45
13.58	10.15	0.50	0.41	0.50
13.58	13.86	0.37	0.41	0.41
12.50	14.11	0.36	0.45	0.45
12.50	6.47	0.76	0.45	0.76
12.50	7.61	0.66	0.45	0.66
12.50	24.42	0.21	0.45	0.45
11.64	13.86	0.37	0.45	0.45
11.43	28.64	0.18	0.49	0.49
11.00	20.20	0.25	0.51	0.51
10.57	10.27	0.49	0.53	0.53
10.35	9.64	0.52	0.54	0.54
Average value of time:		0.50	0.41	0.57
Standard deviation:		0.28	0.09	0.24
Median value:		0.47	0.45	0.47

Table 4. *Estimates of the value of time spent hauling water for households choosing open wells (US$)*

1	2	3
Time required to collect water from Wells (in min)	Kiosks (in min)	Upper bound estimate on value of time, Minimum of P_v/COL_w or $P_k/(COL_w - COL_k)$
12.50	14.65	0.45
12.50	8.15	0.45
12.20	10.12	0.46
10.80	12.53	0.52
10.30	8.00	0.54
9.90	10.46	0.57
9.90	9.14	0.57
9.60	10.32	0.58
9.20	11.00	0.61
Average value of time:		0.53
Standard deviation:		0.06
Median value:		0.54

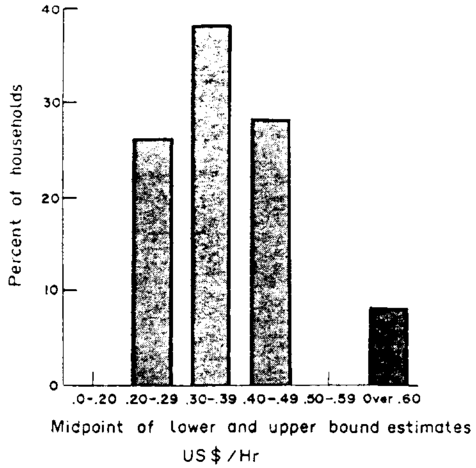

Figure 1. *Frequency distribution of the estimates of the value of time for households choosing kiosks.*

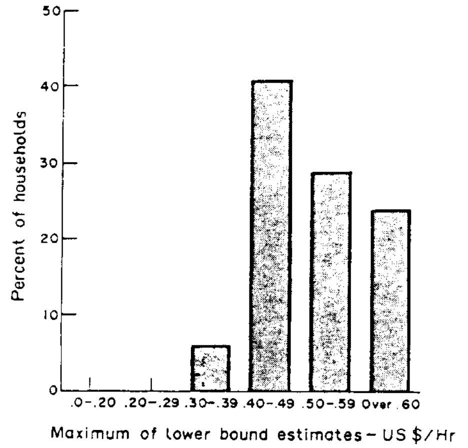

Figure 2. *Frequency distribution of the estimates of the value of time for households choosing vendors.*

Similarly, these estimates of the value of time are consistent with the data on the average number of women in different groups of households. Because women collect about 75% of the water fetched by households in Ukunda, one would expect that households with more adult women would have a greater labor supply for hauling water, and would thus be less likely to purchase water from vendors. This is, in fact, the case. Households using vendors average only 0.88 women, while households using kiosks average 1.45 women, and households using open wells average 1.78 women.

(b) *An estimate of the value of time based on a random utility theory approach*

In Section 2, we derived upper and lower bounds for the value of time spent hauling water based on the assumption that the households' source choice decisions depend only on the time spent collecting water and the cash price paid for water. In this section, we relax this assumption and take into account other factors which may affect source choice decisions, such as the quality of water at the different sources.

As discussed in Section 2, a more complete model of households' source choice decisions would posit that the utility a household derives from a water source would depend upon at least two sets of explanatory variables: (i) source attributes which affect the household's utility, and (ii) household characteristics which reflect differences in tastes and preferences among households. Let X be a vector of source characteristics, and Z be a vector of household characteristics. The conditional indirect utility function of household h may be written as:

$$U_{ih} = U_{ih}(X_{ih}, Z_h) \qquad (21)$$

where again i indicates the water source and h denotes households. Since the utility U_{ih} is not directly measurable, researchers attempt to estimate the utility U_{ih} from the observed independent variables X_{ih} and Z_h. Such an approximation of U_{ih} will be subject to error, and, as a result, some inconsistencies in observed behavior are generally inevitable (as indeed was the case in the data analysis presented in the last section).

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 (or observed) term in the household's random utility function (Manski, 1973; Ben-Akiva and Lerman, 1985). Thus, in our example the random utility function is:

$$U_{ih} = V_{ih} + e_{ih} \qquad i \in J \qquad (22)$$

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:

$$y_{jh} = \begin{cases} 1 & \text{if } V_{jh} + e_{jh} > V_{ih} + e_{ih} \quad i,j = 1, \ldots J \\ 0 & \text{otherwise} \quad i \neq j \end{cases} \qquad (23)$$

The expected value of y_{jh} is thus:

$$E(y_{jh}) = P(y_{jh} = 1) \qquad (24)$$

$$= P(U_{jh} > U_{ih}) \qquad (25)$$

$$= P(V_{jh} + e_{jh} > V_{ih} + e_{ih}). \quad (26)$$

In other words, the probability that household h chooses alternative source j equals the probability that the utility derived from using source j is greater than the utility derived from any other alternative (Amamiya, 1981; McFadden, 1973, 1982).

Based on this random utility framework, we postulate the following utility function for household h choosing water source i:

$$U_{ih} = V_{ih}(\text{TIME, CASH, TASTE, INCOM, WOMEN, EDUCT}) \quad (27)$$

where

TIME = total time spent collecting water per day, including travel time, queue time, and fill time (minutes per day);

CASH = total amount of money paid for collecting water per day, i.e., the cash price times the amount of water consumed per day (US$ $\times 10^{-2}$ per day);[15]

TASTE = household's perception of the taste of water from the open wells — equal to one if the taste is poor, zero otherwise;

INCOM = total annual household income (in thousands of Kenyan shillings);

WOMEN = number of adult women in the household;

EDUCT = number of years of formal education of family members.

The means of the independent variables are presented in Table 5 for households in Ukunda which chose each of the three types of water source.

The three source characteristic variables — TIME, CASH, and TASTE — are all expected to have a negative effect on the probability of a household choosing a particular source because people prefer to spend less money and less time collecting water, and they prefer better tasting water. The household characteristic variables INCOM and EDUCT are expected to have a positive influence on the probability that a household chooses a vendor or a kiosk. The household characteristic variable WOMEN is expected to increase the probability that a household chooses a kiosk or an open well because the more women in a household, the more labor is available for carrying water to the home.

Since the distribution of U_{ih} depends on the distribution of e_{ih}, different assumptions about the distribution of e_{ih} will lead to different discrete choice models. Here we assume that e_{ih} has a Gumbel distribution so that the probability of choosing a source will have a logit-type function (Ben-Akiva and Lerman, 1985). Note

Table 5. *Mean values of independent variables used in the conditional multinomial logit model of water source choice*

Independent variable	Households using Kiosks	Vendors	Open wells	Total for all households
CASH (US$ $\times 10^{-2}$ per day)	4.25	42.46	0.00	18.37
TIME (Minutes per day)	41.39	0.00	57.90	34.68
TASTE (1 = poor; 0 = otherwise)	0.19	0.14	0.91	0.42
INCOM (10^3 Kenyan shillings per year)	20.74	32.46	19.05	23.24
WOMEN (Number of)	1.45	0.88	1.78	1.36
EDUCT (Years)	12.75	12.45	8.13	11.81

that the independent variables in the random utility function which describe the source attributes vary across sources; the independent variables which describe the household's socioeconomic characteristics do not vary across sources (the latter group of variables are included to explain variations in tastes across households). The standard statistical method for dealing with the first group of independent variables is a logit model; the standard approach for the second group of independent variables is a polychotomous model. McFadden (1973, 1976, 1982) and Maddala (1983) have developed the following conditional logit model to deal with a data structure which includes both groups of independent variables:

$$P_h(j) = \exp(BX_{jh} + \alpha_j Z_h) \Big/ \sum_{i=1}^{J} \exp(BX_{ih} + \alpha_i Z_h) \quad (28)$$

where it is assumed the household's utility function is additive:

$$V_{ih} = BX_{ih} + \alpha_i Z_h.^{16} \quad (29)$$

The results of the model estimation are presented in Table 6. The overall model is highly significant; the adjusted likelihood ratio is 0.51. The signs of all of the explanatory variables are as expected. The two variables TIME and CASH, which are used to calculate the value of time, are both significant at the 1% level.

The purpose of presenting this discrete choice model in this paper is to derive an estimate of the value of time spent hauling water.[17] If the value of time is defined as the marginal rate of substitution between the time spent collecting water and the money paid for the water, it can be calculated from two of the estimated parameters of this conditional multinomial logit model. The value of time is simply given by the ratio of the coefficients B_1 and B_2.[18] The value of time spent hauling water may thus be calculated as:

$$\begin{aligned} \text{Value of time} &= (B_1/B_2) \quad (30) \\ &= (-0.053/-0.101) \\ &= \text{US\$0.0052 per minute} \\ &= \text{US\$0.31 per hour} \end{aligned}$$

This result is almost 25% more than the market wage rate for unskilled labor in Ukunda in 1986 of US$0.25 per hour. This estimate of the value of time spent hauling water should be interpreted as an average for the households in the sample, in contrast to the estimates of the value of time derived using the "revealed preference" inequalities, which were household specific.

5. CONCLUSIONS

We feel that both procedures outlined in this paper have significant potential for yielding insights into the value households place on the time spent collecting water. Although the upper

Table 6. *Results of the conditional multinomial logit model of households' water source choice*

Variable	Coefficient	Standard error	t-Ratio	Significance level
TIME	−0.05	0.02	−3.1	0.00
CASH	−0.10	0.03	−3.0	0.00
TASTE	−0.36	0.56	−0.6	0.52
V-INCOM*	0.09	0.05	1.8	0.07
V-WOMEN	−1.01	0.60	−1.7	0.09
V-EDUCT	0.08	0.07	1.1	0.25
K-INCOM	0.04	0.04	1.0	0.33
K-WOMEN	−0.34	0.37	−0.9	0.36
K-EDUCT	0.01	0.06	1.6	0.11
Log-likelihood ratio:			−46.0	
Restricted log-likelihood ratio:			−75.8	
Chi-squared:			0.56 E-11	
No. of observations:			69	

*The coefficients of the independent variables prefaced by *V* and *K* indicate the change in the log-odds of choosing that particular source (i.e., *V* = vendor and *K* = kiosk) relative to the omitted source (an open well).

and lower bounds on the value of time for those households which chose kiosks were farther apart than we might have wished *a priori*, we interpret the evidence to indicate that the value of time spent collecting water for most households which chose kiosks is likely to be near — or even above — the market wage rate for unskilled labor. The lower bounds on the value of time for households which chose kiosks suggest that the value of time spent collecting water is *at least* 50% of the market wage rate (Table 2). Households using vendors appear to have a significantly higher value of time than households using kiosks, and in absolute terms, the lower bounds on the value of time for households choosing vendors (Table 3) are much higher than we would have anticipated (more than twice the market wage).

Our estimate of the average value of time derived from the parameters of the conditional multinomial logit model is surprisingly close to the current market wage for unskilled labor. If additional research shows that the value of time spent hauling water in other villages in developing countries is close to the market wage rate for unskilled labor, this result will have important policy implications for choice of service level. If the value of time spent hauling water is as much as US$0.25 per hour, piped distribution systems are an economically attractive technology in many villages in developing countries (Churchill *et al.*, 1987).

In closing, it is important to emphasize that the estimates of the value of time spent collecting water which are presented in this paper should be considered preliminary. Additional research should be carried out in other locations to determine whether these results may be generalized to other communities in Kenya, and to different countries and cultures. Future research efforts on this subject should also improve upon the study presented here in three important respects. First, the sample size should be increased so that one can place more confidence in the magnitude of the estimates of the value of time. Second, in-depth anthropological investigations should be carried out to determine whether social, cultural, and political factors also influence households' water source choice decisions. Third, future research efforts should examine whether households' value of time varies significantly by hour of the day, day of the week, or season of the year.

NOTES

1. See Becker (1977) and Evans (1972) for an introduction to some of the theoretical work on the valuation of time.

2. For a more formal treatment of the theoretical framework presented in this section, see Ben-Akiva and Lerman (1985), pp. 43–48.

3. See Whittington, Briscoe, and Mu (1987) for a presentation of a discrete-continuous model of household water demand.

4. A water "kiosk" is generally a small structure which sells water to customers on a volumetric basis. The source of water may be privately or publicly owned.

5. We use the term "taste" here to refer not only to the "flavor" of the water (as experienced by taste buds on the tongue), but to all dimensions of a consumer's preferences for a particular water source except money, price, and collection time — including, for example, the consumer's perception of the health effects of water from various sources.

6. Both of these assumptions are true for the case study described in this paper.

7. Note that B_1 and B_2 are negative, so that U_v/B_1 and U_k/B_1 are negative.

8. Recall that $(COL_{wh} - COL_{kh})$ is assumed to be positive; see discussion of Case 1.

9. For a more detailed description of the Ukunda field study, see Whittington, Lauria, Okun, and Mu (1989).

10. In strict Islamic cultures, women may be discouraged from queuing at wells or kiosks in full view of the general populace. This was not, however, a factor in Ukunda in preventing women from using these water sources.

11. In 1986, US$1 = 16 ks.

12. Although households were asked about their perception of the quality of water from different sources, no bacteriological or chemical tests of water samples from different sources were carried out.

13. This estimate of the quantity of water collected per trip is based on source observation data. There is little variance among households; the vast majority of adults use standard 20-liter containers to carry water.

14. Two of these five households chose kiosks even though the total collection time for the open well was less. Such decisions could be due to poor taste or other water quality characteristics of the open wells.

15. Note that this variable is defined as price times quantity of water rather than simply the price of water. This is necessary in order to derive an estimate of the value of time (see Bruzelius, 1979; and DeSerpa, 1971).

16. 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 easily transformed into a choice-specific vector. Therefore, the maximum likelihood method will give a consistent estimate of the parameter vector B.

17. For a more detailed presentation of the results of the discrete choice model of households' water source selection decisions, see Whittington, Lauria, Okun, and Mu (1988).

18. See Ben-Akiva and Lerman (1985), pp. 75–80 and 174–177, and Stopher and Meyburg (1976) for detailed discussions of the derivation of the value of time based on this random utility framework.

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