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How Bengali Villagers Choose Sources of Domestic Water

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INTRODUCTION

It is widely believed that the health of people in rural Bangladesh (and other Third World countries) would be greatly improved if these people used increased quantities of water of a higher bacteriological quality for domestic purposes. Rural water supply programs are usually designed on the assumption that if access to an "improved" supply is easy and if the people are educated about the beneficial health effects of abandoning their traditional supplies and using this new supply, then existing water use patterns will change. Observations of the effect of such programs on the behaviour of rural people in many parts of the world (White *et al.*, 1972) raise serious doubts as to the adequacy of this simple behavioural model. People frequently do not respond in the desired or expected manner to the availability of "improved" water sources. These failures are usually attributed to technical design deficiencies or to the lack of health awareness of the people; the solutions are thus better engineering and more health "education".

The approach taken in this paper is quite different. It is assumed that present water use habits are not the result of ignorance or the lack of availability of "safe" water, but that villagers have well-formed opinions concerning the characteristics of available water sources. They know how far a source is from their home; whether there is likely to be a quarrel if they use the source; whether the water is clean, the colour good and the taste pleasant; whether the place is private and the ghat[1] of good quality; whether the water is deep. They choose water sources for different domestic purposes—drinking, cooking, washing utensils, washing clothes and bathing—in accordance with these perceptions. The relative importance of these different factors is expected to vary with social and economic status. The corollary of these assumptions is that only when planners have a more subtle understanding of existing water use patterns and preferences will they be able to predict who will use a particular new source and for what purposes they will use it.

In designing water programs planners are also hampered by our ignorance about how water-related behaviour affects disease. It has been shown (Briscoe, 1978) that epidemiologists are often unable to relate the incidence of, say, cholera to water use patterns

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[1] A ghat is a structure providing access to a water source. The quality of a ghat may vary from a muddy embankment to a concrete structure.

simply because they do not know how people actually use water. A better understanding of water use patterns and perceptions is thus needed if planners are to know both how people will respond to water supply programs and how this response will affect health.

THE THEORETICAL FRAMEWORK

Background

In 1972, White *et al.* published a study of how East African villagers choose among different water sources for domestic purposes. The families were interviewed and for each accessible source their perceptions were elicited regarding the perceived quality of water, the economic feasibility of obtaining water and the technological feasibility of drawing water. For each accessible source the perceptions for each factor were recorded as "unfavourable", "neutral" or "favourable" and given rankings of 0, 1 and 2 respectively. A similar procedure was followed for assessing the effect of use of this source on relationships with other people. The scores were combined to produce an index of the "attractiveness" of each source to each user.

The analysis was useful in several ways. It was an important step in drawing attention to the fact that user's reactions are based on their *own* perceptions of the situation and not the perceptions of scientists or government officials. The formal model was useful in guiding the systematic collection of data which, in the raw form, gave interesting insights into why some sources were preferred to others. The analysis was also a landmark in being the first attempt at formally understanding how people choose the water source they will use.

There are, however, three serious deficiencies in White's analysis. The first problem is that the model is *ad hoc.* The attractiveness index is obtained by multiplying the scores for quality, economic feasibility and technological feasibility and subtracting the score for "effects on others" from this product. The index is presented as "reasonable" but no attempt is made to relate the model to any rigorous theory of behaviour. The second problem relates to the simultaneous consideration of all types of domestic water use. In the present study, where 65% of the families use more than one source of water for domestic purposes, and apparently in East Africa, each factor affects each type of water use differently. Water quality, for instance, may be a most important consideration when a person chooses a source of drinking water but may be largely irrelevant when the person chooses a place to wash clothes. The third problem is that while White's model was developed as an explanatory model, only a few illustrative examples are given and the predictive power of the model never tested on all of the data which were collected. The model presented in this paper is an attempt to build on that which White started but to avoid some of the problems which limit the usefulness of White's analysis.

The model

The theory of consumer behaviour concerns the choice of a bundle of goods when the prices of these goods, the budget and the consumer's preferences (in the form of indifference curves or an ordinal utility function) are known. The "two-good" case is presented on Fig. 1. This theory is routinely used to examine the effects of changes in prices of the goods and income level on the demand for these goods. If this framework is used to try

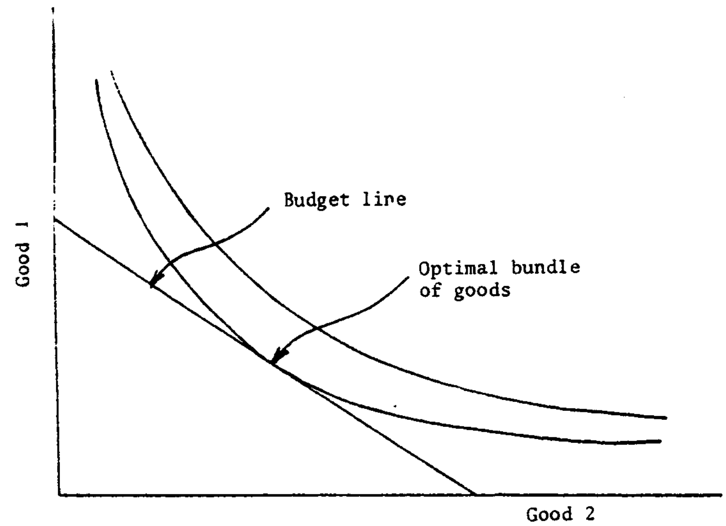

Fig. 1. The standard consumer behaviour paradigm.

to understand the water choices exercised by villagers and to predict their response to a new water source, several problems are immediately apparent. This case is different since the attempt is to understand the choices, not among goods, but among different sources of the same good, with each source having a particular set of "characteristics". In this case there are no analogies to the concepts of "prices" and "income" and use of a source is not divisible but a yes/no matter.

In response to similar difficulties which have arisen in other areas—such as in estimating the demand for presently unavailable forms of transportation (Quandt & Baumol, 1966)—a "new" approach to consumer theory has been developed (Lancaster, 1971). In this view consumption goods, as such, are not immediate objects of preference or utility but have associated with them "characteristics" which are directly relevant to the user. The user is assumed to have a preference ordering over the set of all possible characteristic vectors and her aim is to attain the most desired bundle of characteristics subject to the constraints of the situation. As an example of the use to which this framework will be put, the situation facing Anwara Nessa, a poor mother in the study village is illustrated in Fig. 2.

All members of Anwara's family bathe at river ghat 200 which is several hundred yards from their house. Anwara draws drinking water from this ghat but brings cooking water from tank[2] 67 which is about 100 yards away. She also washes clothes and utensils at this tank. Tubewell[3] I, which is as far away as the river, is not used by the family but is perceived to be an alternative water source. They have no quarrels over the use of any of the sources since they are joint owners of the tank, the river-bank is a public place and the tubewell was installed by the Government. As our subsequent analysis will show, distance and taste are the characteristics most important in choosing a drinking water source. In Fig. 2 the available water sources and the preference function for the family

[2] A tank is an artificial reservoir, usually excavated to obtain earth for flood-protecting house-mounds and for the houses themselves.

[3] A tubewell is a small-diameter cased well fitted with a cast-iron suction handpump.

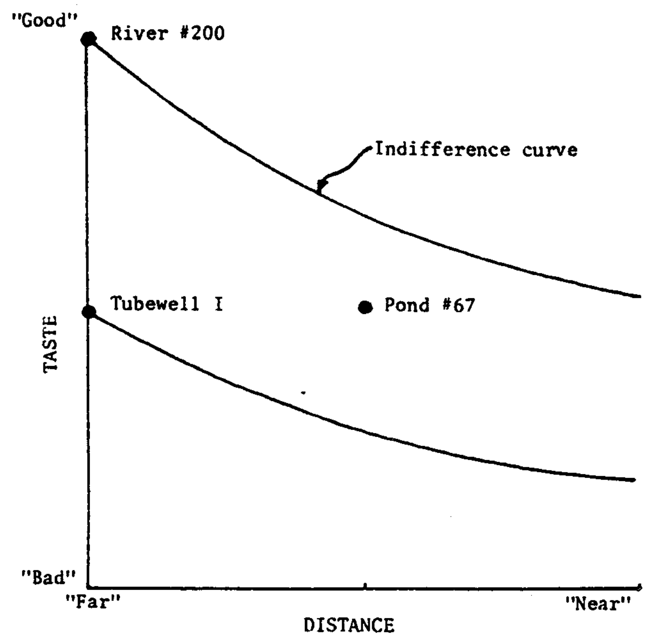

Fig. 2. The choice of drinking water by a poor family.

are plotted. Figure 2 shows that the choice exercised by the family in choosing a drinking water source is consistent with the preference function of their socio-economic group.

This method of analyzing consumer choice differs from the standard approach in several important ways. A utility function is usually thought of as describing a consumer's preferences among different bundles of goods. In terms of the "new" theory, the standard utility function incorporates both preferential and technical considerations, the latter because the relationship between goods and characteristics is subsumed into the utility function. For this reason this standard approach cannot be used to predict the reaction to the availability of a new good or a new source of an existing good.

A feature of the "new" approach is the separation of technical and preferential issues. After selection of the characteristics which are relevant to consumer or user choice, the goods-characteristic relationship and thus the efficiency frontier (the points "river 200", "tank 67" and "tubewell I" on Fig. 2) are specified without reference to the preferences of the user[4]. The indifference curves embody the people-characteristic relationship and are estimated by examining behaviour. In graphical terms, a "budget line" no longer exists: There is now an "efficiency frontier" which maps the vectors of available characteristics for a given set of prices and income. In this type of analysis real income differences may appear as scalar changes in the typical frontier or, in this case, as new options which embody a previously-unavailable vector of characteristics.

Understanding water-use choices is largely an exercise in elucidating ways in which users are willing to substitute one characteristic for another characteristic in order to

[4] Ideally this relationship is "technical" and is measured objectively or by an engineer. In our analysis we use subjective evaluations, a procedure which introduces no theoretical difficulties if the evaluations are consistent. It is required, for example, that most users would agree that the colour of water from a certain source is "good", or that most observers would agree that a particular source is "far" from a particular family.

maintain a given level of satisfaction. Each form of the ordinal user's preference function implicitly specifies the marginal rate of substitution (MRS) which is the rate at which this substitution of one characteristic for another takes place. Choosing an appropriate user's preference function is the art of striking a judicious balance between a simple form (which is analytically tractable but implies a restrictive set of substitution properties) and a complicated function (which implies few restrictions but requires the estimation of many parameters and is analytically intractable).

At the very least it seems reasonable to require that it becomes increasingly difficult to substitute one characteristic for another as the substitution proceeds, that is, the user's preference function should be convex to the origin. As an example of the implications of a choice of a particular form for the user's preference function consider the multiplicative function chosen by Gilbert White. Recalling that the function

$$Y = X_1^{\alpha_1} X_2^{\alpha_2} \dots X_n^{1-\alpha_1 \dots -\alpha_{n-1}}$$

is the well-known Cobb–Douglas function, it can be seen that the simple multiplicative form used by White is a special case of the Cobb–Douglas function, with $\alpha_1 = \alpha_2 = \dots = \alpha_{n-1}$. (The fact that the exponents do not sum to unity in White's simple multiplicative form is irrelevant since behaviour is unaffected by a monotonic transformation of the preference function).

Since MRS of 1 for 2 $= (\partial Y/\partial X_2)/(\partial Y/\partial X_1) = \alpha_2 x_1/\alpha_1 x_2 = x_1/x_2$ for a simple multiplicative function, the *ex ante* specification of the exponents by White was unnecessarily restrictive. No parameters are estimated from the data and thus the marginal rate of substitution between characteristics is uniquely and arbitrarily defined for the user's preference function.

Use of the Cobb–Douglas function has been restricted in the traditional theory of consumer choice since income elasticities (the relative change in the quantity of the good divided by the relative change in income) for all goods is unity and the elasticities of substitution between goods (which measures how fast the MRS increases) are unity. More general functional forms, in which these restrictions are relaxed, are available. In the Constant Elasticity of Substitution function, for instance, the elasticity of substitution is not specified *a priori* but estimated from the data.

Lancaster (1971) has argued that these restrictive properties of the Cobb–Douglas function are mitigated if the standard concept of a "representative consumer" is abandoned and different preference functions are estimated at different income levels. If this is done a particular individual is no longer required to have the same preference parameters at different income levels. For the analysis of water-use choices the Cobb–Douglas form of the user's preference function appears to be an appropriate choice since it is analytically tractable but not unduly restrictive if the population is stratified by income level.

Calibrating the model

In the standard consumer behaviour paradigm, consumers who have a given level of income and who are faced with a set of market prices choose that bundle of goods which maximizes their utility. In the standard paradigm it is reasonable to assume that individuals who have similar incomes will be reaching approximately the same utility level.

Therefore the parameters of the utility function for a group of individuals who have similar incomes may be estimated by pooling all data on individual consumption choices.

The present case is quite different. It is assumed that individuals of the same economic status have similar preferences and thus the same indifference curve parameters. However, within an economic group individual water supply endowments may vary considerably and thus the utility levels obtained from consumption of water may be quite different for different individuals.

Since it is difficult to elicit useful data from questions on hypothetical situations—"If the water source which you presently use was not available, which source would you use for drinking?"—the "revealed preference" approach to consumer behaviour was used. Information was obtained on actual behaviour and from this information certain properties of the underlying preference orderings were deduced. This approach restricts the available data set since it is not possible to rank all of the water sources which are accessible to a family. The only justifiable ordinal comparisons are between the source which is chosen and each of the sources which are not chosen by the family. The resulting data are peculiar. Even ordinal comparisons between the preference levels of the individuals within the same economic group cannot be made and even within a single family we have an incomplete set of pair-wise comparisons of water sources. Because of these peculiarities no standard statistical techniques for estimating the preference function parameters can be used and so the following procedure for estimating the parameters of the Cobb–Douglas user's preference function for each economic group was adopted.

When a family chooses a source for, say, drinking water this implies that the family makes pair-wise comparisons between the chosen source and each of the rejected sources. For a given parameter vector the model assigns a value of the preference function to each source available to each family. The results of the actual and predicted pair-wise comparisons are compared and the number of rankings which the model has predicted correctly are recorded. The criterion for choice of a parameter vector is to choose that vector which maximizes the proportion of correct pair-wise comparisons.

THE FIELD STUDY

In investigating subjects about which knowledge is rudimentary the primary task of researchers is to formulate the correct questions, not to try to get a comprehensive set of answers. In-depth analyses of closely-observed samples has been the most fruitful method in this primary stage of most economic and sociological investigations (Lipton & Moore, 1972). Since knowledge of water-use perceptions and patterns is certainly no more than rudimentary, our study was based on an in-depth study of a small number of families in the village of Panipur for 1 yr, followed by more rapid and superficial surveys of one month each in different ecological zones of Bangladesh. Due to unforeseen circumstances only nine months of data from Panipur were collected and the second part of the study was not carried out.

The village and domestic water sources

Panipur is located in the deep-water flooding plain of the Meghna River. For protection against inundation by the annual flood-waters the villagers build their homes on earthen mounds. Consequently the inhabited areas are flanked by depressions which fill with water during the monsoon. Where these depressions remain amorphous and unimproved they are known as "ditches"; where embankments are raised around a well-defined perimeter these water sources are known as "tanks". Many of the villagers also have access to one of the many natural water courses which criss-cross the active Ganges–Brahmaputra delta. In Panipur there are three such water courses. The largest of these is known as "the river" and the two smaller ones as "canals". The 1800 inhabitants of the village can also pump groundwater, which usually has an undesirably high iron content, through one of the eight handpump tubewells which have been installed by the government for public use. There are three private tubewells in this village.

The method

After spending two months learning Bengali, the senior author spent one month in Panipur observing how people used water and listening to villager's opinions concerning their sources of domestic water supply. He then spent two months drawing up the theoretical framework for the analysis before returning to live in Panipur. For the next two months the two co-investigators (MC and SA), both of whom are local women, worked with the senior investigator in specifying which factors should be included in the analysis and in developing a method for generating the required data. Careful and critical attention was paid to the hazard of failing to elicit complete replies and to the converse risk of biasing the response through the mode of enquiry. After six preliminary formats had been tried and discarded a format which proved to be satisfactory was adopted.

In living and working with the people of Panipur for a year the investigators developed good relationships with many of its people. A substantial portion of the interviewer's time was spent helping women do their house-hold work, looking after their children and telling stories, and thus the interviewers were able to interview only two families each per day. It was essential to inconvenience the study families as little as possible since it was planned to interview them four times during the course of the year and a high degree of cooperation was necessary to obtain accurate and complete information.

The study families, which were selected randomly from 365 families of the village, were divided into three groups of about 60 families each. Each family was to be interviewed at three monthly intervals. The first two days of each month were spent updating the map of the available water sources in the vicinity of the families who were to be interviewed that month. This was necessary because of the pronounced seasonal changes in the hydrology of the area. Each water source was given a code number and brief descriptions of the quality of the ghat and the water quality were recorded. Over the next two days the head female of each study family was asked which sources of water the family used at that time for each domestic purpose. Using the village map, the water use patterns of the family and its neighbours, a number of sources—usually three or four—were designated as "accessible" to this family. In the field the interviewer would ask the woman again which sources she used for collecting drinking and cooking water, where she washed utensils and clothes and where the different family members bathed. If there were any discrepancies between these answers and the information obtained earlier these were resolved. The distance of each source from the house was recorded.

Information was then collected on which water-related tasks were performed at home and which were done at the water source. The number, type and size of the kolshis[5] used for carrying water for drinking, cooking and other uses were recorded. The number of times each kolshi was filled with water over the last 24 hr was recorded as was the name of the person who carried the water and the time of day when the water was carried. A brief set of questions was asked concerning the source of ablution water for different family members.

The heart of the questionnaire and the part which was most difficult to develop, is the section designed to furnish information on the user's perceptions of the characteristics of each of the accessible sources. For each accessible source two pages of questions, as shown on Fig. 2, were asked.

Table 1. The questions on perceptions of accessible water sources

Accessible water source (number and type): 101-b (tank)	
(Left hand page)	(Right hand page)
1. Do you think this is a good source of drinking water? Yes ___ No _✓_. Why? *The tank is far from our house. There is rotting water hyacinth in the water so it does not taste good.*	1. _✓_ Distance. For any purpose, does distance affect your use of this source? 2. ___ Colour. For any purpose, does colour of this water affect your use of this source? *The water is red so it is unsuitable for drinking, cooking and washing clothes.*
⋮	⋮
8. Do you think this is a good source for men's bathing? Yes ___ No _✓_. Why? *My husband bathes here. The place is good because the water is deep, but is owned by others and so there are frequent quarrels.*	10. _✓_ Quarrels or friendship. For any purposes do quarrels or good relationships affect your use of this source?

Using the "left hand page" questions, the user was questioned on her perceptions of the particular source for each of the domestic uses and her answers were recorded in full (in Bengali). If she mentioned, for example, that the source was far (or close), then the question regarding "distance" on the "right hand page" was checked off. After the "left hand page" was completed, those "right hand page" questions which had *not* been checked off—there were usually one or two of these—were asked. Perceptions thus were recorded regarding all of the factors—distance, colour, odour, taste, dirt, privacy (or purdah), depth (or difficulty of pumping if the source was a tube-well), quality of ghat, and quarrels or friendship—which earlier trials had suggested affected the attractiveness of a particular water source.

For each of the accessible sources a pair of pages were filled out. On a few occasions the respondents were not familiar with a source which they were asked about. These sources were dropped from the list for that particular family. The questionnaire was concluded by asking whether any family members had had diarrhea over the last three days and whether any were suffering from scabies.

[5] A kolshi is a narrow-mouthed water carriage and storage vessel, usually made of pottery.

The standard procedure was to collect all information from adult women in each family, since it is they who are responsible for all domestic work. Since there were legitimate questions as to whether adult males and children have similar perceptions of their water source, a sample of men and children were also interviewed. Their responses were found to be almost identical to those of the adult women.

For the quantitative analysis it was necessary to translate the verbal responses into "scores"—1 if the individual's perception of the factor was "unfavourable", 2 if "ambivalent" and 3 if "favourable". Since this is obviously a risky procedure, the assessments were cross-checked by asking the respondents another set of questions during our third three-monthly round. For each accessible source they were asked whether they considered each factor to be "unfavourable, neutral or favourable". These responses were subsequently checked against the scores which were assigned on the basis of the verbal answers. There was close agreement, suggesting that the informal procedure for assigning scores to verbal answers was satisfactory.

This short-hand method was not seen as a substitute for the more laborious verbal method incorporated into the main questionnaire. Throughout the study a high premium was placed on collecting information which did not fit into the structured scheme. It was found that the verbal method encouraged the villagers to tell all that they thought about water. The short-hand method never elicited similar interesting responses.

RESULTS

In the first part of this section the results for the post-monsoon period are presented in detail. Subsequently the more important of these results are compared with results from the data collected during the pre-monsoon and monsoon periods.

Water use during the post-monsoon period

Due to the premature termination of the study, land ownership data for all study families are not available. The only available measure of economic status is the square foot of living area *per capita*. On this basis the population was stratified into a "rich" (more than 60 square feet *per capita*), a "medium" and a "poor" (less than 40 square feet *per capita*) group, containing respectively 54, 49 and 40 families. For each group the estimation algorithm was run three times.

In the first run all independent variables were included with the exponents of the characteristics specified by random numbers. The "% correct pair-wise comparisons" were computed for 200 parameter vectors. The optimal parameter vectors appear to be unstable for all groups and for all uses. An example of this instability is given on Table 2, where the four best predictor vectors for the drinking water patterns of the poor group are listed.

Table 2. Parameter values for the four best predictor vectors: The choice of drinking water sources by the poor

Predictor vector:	Distance	Colour	Odour	Taste	Dirt	Purdah	Quarrels	Depth	Ghat
Best	0.179	0.000	0.071	0.321	0.107	0.107	0.179	0.000	0.036
2nd Best	0.146	0.146	0.171	0.122	0.049	0.049	0.146	0.024	0.049
3rd Best	0.158	0.018	0.140	0.158	0.123	0.123	0.140	0.070	0.070
4th Best	0.026	0.237	0.211	0.211	0.079	0.079	0.211	0.000	0.000

In a standard statistical model this instability, which stems primarily from multicollinearity among the independent variables, would be manifested in the form of high standard errors on the parameter estimates. This problem is addressed later in this paper.

Examination of the results of these random explorations of the complete sample space is nevertheless, revealing. It is clear that water uses divide into two sets of uses: the parameter vectors which give good predictions for drinking water give poor predictions for all non-drinking uses, while the parameter vectors which predict any of the "non-drinking" uses accurately predict all other non-drinking uses well but drinking water poorly. This dichotomy is clear in all subsequent analyses. Including, as is done in these runs of the model, all of the independent variables, the "% of correct predictions" is highest for drinking water and lowest for men's bathing with clothe washing, utensil washing, cooking, women's bathing, girl's bathing and boy's bathing (in that order) having intermediate "predictability". The "best" predictor of drinking water gets 89% of the eligible pair-wise comparisons correct, while the comparable figure for men's bathing is 80%. (On the basis of dominance alone the water use patterns for 28% of the study families only can be specified.) These maximum values of the "% of correct predictions" provide a standard against which to gauge the satisfactoriness of subsequent predictions in which the number of independent variables is limited.

In the second run of the estimation algorithm all characteristics were included with parameter values of 0.0, 0.5 or 1.0. This "screening model" was used to decide which variables should be used in specifying the dimensions of a smaller independent-variable sample space for subsequent, more thorough exploration. As examples of what is learnt and how the results of these apparently over-restricted runs are used, the results when each characteristic is used alone as a predictor of drinking water use (Fig. 3) and the predictive value of distance alone on each type of water use (Fig. 4) are presented.

Figure 3 shows: that distance and quarrels are powerful determinants for the poor but substantially less powerful for the rich; that odour and taste are the most important

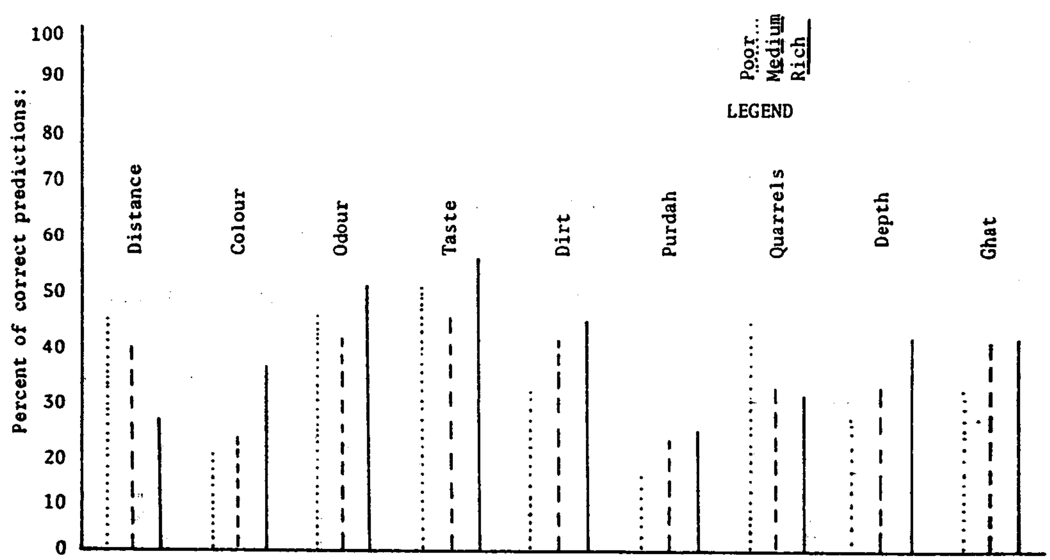

Fig. 3. Single characteristics as predictors of the choice of drinking water source.

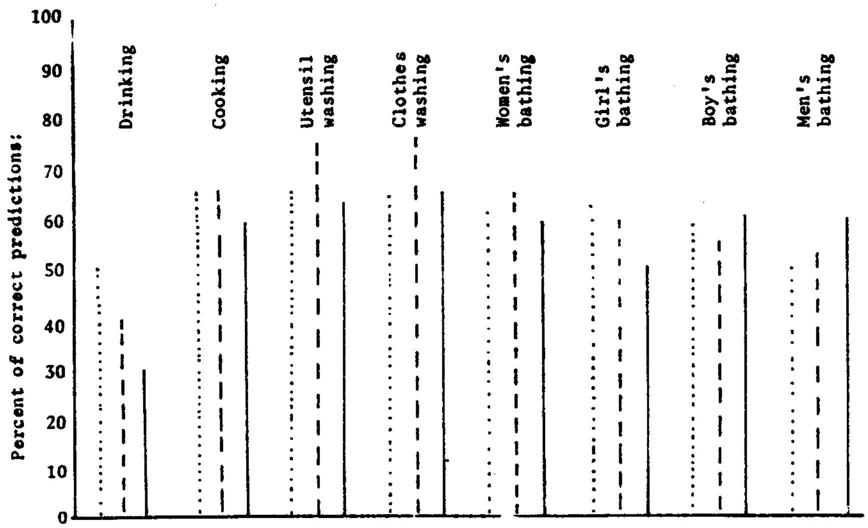

Fig. 4. The predictive value of distance alone.

water quality variables; that all quality factors—colour, odour, taste, dirt, depth, purdah and ghat quality—are more powerful predictors for the rich than for the poor. Figure 4 shows: that distance is more important for all other uses than it is for drinking; that distance is a stronger determinant for poor than rich for all uses other than boy's and men's bathing; that distance is most powerful a predictor for cooking, utensil washing and clothes washing, that is for the women's non-drinking water tasks. These results also show that single predictors are substantially inferior to predictors which incorporate two independent variables and that these, in turn, have substantially less explanatory power than models which include all nine of the independent variables.

Using the results of these runs in conjunction with the more intuitive knowledge acquired from both the field work and examinations of the completed questionnaires, the most important independent variables for each purpose are chosen for further analysis. For example, from the field work it is known that odour and taste are highly correlated and therefore one of them (somewhat arbitrarily, odour) is eliminated despite its high predictive value; from the field work it was thought that purdah may be a significant determinant for uses like women's bathing, but the analysis shows that this is not the case for any purpose and it is therefore eliminated from further consideration. (see Fig 3)

The choice of the prescribed sets of independent variables proves to be surprisingly unambiguous. For drinking, it is clear that distance, quarrels and taste are important determinants; for all other purposes distance, quarrels and depth are unambiguously the variables which demand further joint exploration.

Using these limited sets of independent variables the algorithm was run again with the sample space systematically covered for parameter values of 0.0, 0.2, 0.4, 0.6, 0.8 and 1.0. The sensitivity of the results to the exclusion of the excluded variables was tested in two ways: by comparing the "% of correct predictions" with the highest "% of correct predictions" in the first run of the algorithm (with all independent variables and random sampling); and by adding excluded variables and seeing whether they entered the optimal

Run 3

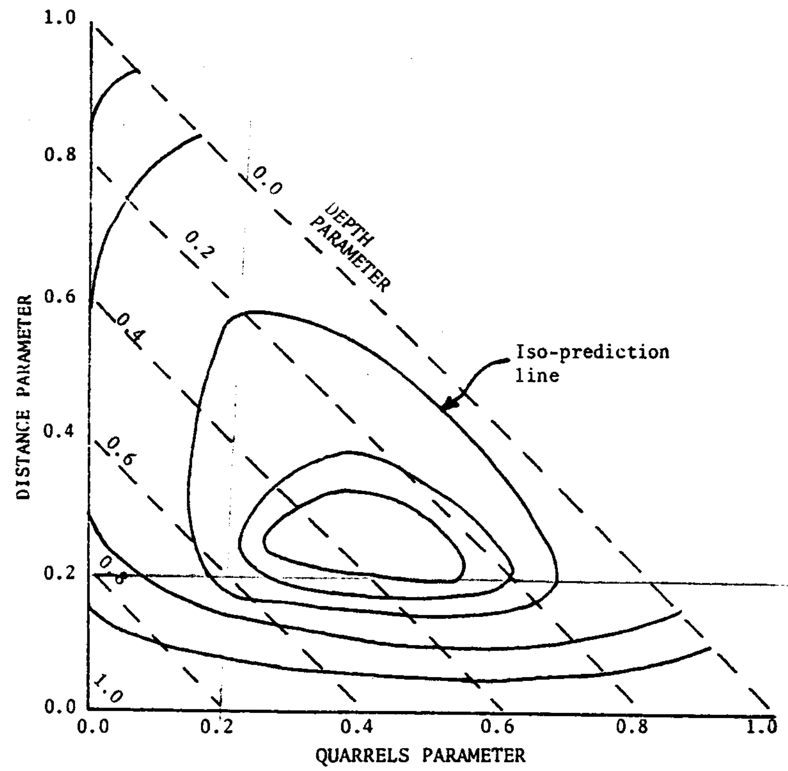

Fig. 5. Predicting the source of cooking water used by poor families.

parameter vector. Both of these tests confirmed the validity of the method used for screening the independent variables.

The fact that only three independent variables entered any of the final prediction equations and that the parameters sum to unity meant that isoprediction lines could be plotted on two-dimensional graphs and optimal parameter values chosen without recourse to further computer analysis. A typical response surface is presented on Fig. 5. The optimal parameter values will be presented later in this paper.

If this analysis were performed on a data set with more conventional properties, the best estimates of the parameters of the Cobb–Douglas function would be accompanied by a standard error of estimate. Information on the sensitivity of the response surface to different parameter vectors is conveyed by specifying that the parameters associated with each of the included independent variables enter the equation with a value of at least 0.2 (the smallest positive value in our sampling frame) and comparing the lowest "% of correct predictions" in the resulting feasible region with the "% of predictions" at the optimal parameter values. These comparisons (listed in Table 3) suggest that for all uses other than drinking, the results are quite insensitive to the particular parameter values. That is, as long as each of the included variables has an exponent of 0.2 or greater, then the performance of the predictor is satisfactory. Only for drinking (and particularly for higher economic groups) a more sophisticated specification of the preference function is needed.

Table 3. The ratio of the lowest % correct predictions in the "feasible region" to the % of correct predictions at optimal parameter values

	Poor	Medium	Rich
Drinking	80%	74%	58%
Cooking	93%	86%	95%
Utensil washing	98%	83%	95%
Clothes washing	98%	84%	93%
Women's bathing	95%	94%	92%
Girl's bathing	94%	93%	86%
Boy's bathing	90%	93%	90%
Men's bathing	92%	93%	93%

Comparing water use perceptions during the pre-monsoon, the monsoon and the post-monsoon periods

Analyses using the methodology presented for the post-monsoon period above were performed for the pre-monsoon and monsoon periods, also. In Table 4 the optimal parameters of the Cobb–Douglas functions are presented.

From Table 4 the effect of water quality, distance and quarrels on the perception of different groups for different types of use in different seasons can be specified.

For all groups in all seasons, the perceived quality has a greater effect on the use of drinking water than on water use for any other purpose. For drinking water, the importance of taste increases with income. In the monsoon, too, water quality is more important for the middle and rich than for the poor, but this effect is much less pronounced than it is in the pre-monsoon period.

For drinking water, the effect of distance changes little with income level, although it is somewhat more important for the rich than the poor in the pre-monsoon season. For non-drinking uses, there do not appear to be systematic differences in the effect of distance across income groups in any of the periods. For the poor, distance is a more powerful predictor of non-drinking water uses than for use as drinking water in all seasons. This is true for the medium income groups, too, but for the rich the effect of distance is quite similar for all types of water use, including drinking. Although quality is important for all income groups for drinking, quality of non-drinking water is relatively much more important for the rich than for the poor.

In the pre-monsoon season, when water sources are scarce and private ownership controls access to the sources, quarrels are a major determinant for those who do not command sources (viz., the poor) but unimportant for the other groups. In the monsoon, when water is available at the edge of the baris, ownership of tanks and other facilities is no longer the controlling factor since, to some degree, all sources become more "public". In this season it is the rich for whom quarrels over the now-disputed sources become most significant.

The behaviour of different income groups in different seasons can also be compared by examining the Marginal Rates of Substitution (MRS's) of different characteristics, which are specified by the ratios of the optimal parameters. In interpreting the MRS's in Table 5, it should be recalled that the MRS of distance for taste represents the amount that distance has to be improved to compensate for a small unit deterioration in taste.

Table 4. The optimal parameters for all groups for all purposes in the three seasons

	Poor			Medium			Rich		
	Taste	Distance	Quarrels	Taste	Distance	Quarrels	Taste	Distance	Quarrels
Drinking	0.31 (0.70) [0.55]	0.20 (0.20) [0.21]	0.49 (0.24) [0.24]	0.80 (0.56) [0.62]	0.20 (0.24) [0.20]	0.00 (0.20) [0.18]	0.70 (0.48) [0.66]	0.30 (0.26) [0.14]	0.00 (0.36) [0.20]
	Depth	Distance	Quarrels	Depth	Distance	Quarrels	Depth	Distance	Quarrels
Cooking	0.00 (0.16) [0.38]	0.30 (0.54) [0.22]	0.70 (0.30) [0.40]	0.50 (0.20) [0.20]	0.50 (0.50) [0.28]	0.00 (0.30) [0.52]	0.45 (0.40) [0.29]	0.40 (0.24) [0.25]	0.15 (0.36) [0.46]
Utensil Washing	0.00 (0.14) [0.39]	0.30 (0.60) [0.21]	0.70 (0.26) [0.40]	0.14 (0.00) [0.10]	0.64 (0.60) [0.60]	0.22 (0.40) [0.30]	0.45 (0.40) [0.31]	0.40 (0.24) [0.25]	0.15 (0.26) [0.44]
Clothes Washing	0.00 (0.14) [0.36]	0.30 (0.56) [0.22]	0.70 (0.30) [0.42]	0.24 (0.24) [0.11]	0.42 (0.36) [0.63]	0.34 (0.40) [0.26]	0.46 (0.40) [0.25]	0.34 (0.24) [0.25]	0.20 (0.36) [0.50]
Women's Bathing	0.00 (0.20) [0.39]	0.30 (0.52) [0.21]	0.70 (0.28) [0.40]	0.60 (0.24) [0.30]	0.40 (0.36) [0.30]	0.00 (0.40) [0.40]	0.46 (0.40) [0.27]	0.24 (0.24) [0.23]	0.30 (0.36) [0.50]
Girl's Bathing	0.00 (0.22) [0.26]	0.30 (0.52) [0.24]	0.70 (0.26) [0.50]	0.60 (0.20) [0.32]	0.40 (0.40) [0.22]	0.00 (0.40) [0.46]	0.54 (0.36) [0.26]	0.34 (0.30) [0.24]	0.12 (0.34) [0.50]
Boy's Bathing	0.00 (0.20) [0.30]	0.30 (0.50) [0.22]	0.70 (0.30) [0.48]	0.46 (0.20) [0.38]	0.24 (0.40) [0.26]	0.30 (0.40) [0.36]	0.40 (0.20) [0.22]	0.20 (0.40) [0.25]	0.40 (0.40) [0.53]

Note: In each set of three numbers, the first (without parentheses or brackets) gives the best estimate of the parameters for the pre-monsoon season; the second (in parentheses) gives the best estimate for the monsoon months; and the third figure (in brackets) gives the best estimate for the post-monsoon months.

That is, if the MRS of distance for taste (α taste/α distance) is higher for group *A* than for group *B*, then taste is relatively more important and distance relatively less important to group *A* than to group *B*.

Comparing drinking with non-drinking water perceptions, Table 5 shows for all groups in all periods, that the MRS of distance for quality is much greater for drinking than it is for any other purpose. Table 5 also shows that the MRS of distance for quarrels is, in almost all cases, lower for drinking water than for all other purposes. That is, for drinking water, quality is of overriding importance and people will frequently go considerable distance and risk having quarrels to obtain what they perceive to be a good quality water for drinking. Quality has less effect on non-drinking uses, while quarrels become a more important determinant.

Comparisons of the MRS's also reveal the following.

Drinking water use—During the relatively dry pre- and post-monsoon periods, the MRS of distance for taste increases as income increases. That is, in these periods, the rich value water quality more than the poor and the rich are less concerned than the poor about the distance of the drinking water source.

Table 5. The marginal rates of substitution of characteristics for the three income groups in the three study seasons

MRS of:	Poor: Distance for Taste	Poor: Distance for Quarrels	Medium: Distance for Taste	Medium: Distance for Quarrels	Rich: Distance for Taste	Rich: Distance for Quarrels
Drinking	1.55 (3.50) [2.62]	2.45 (0.50) [1.14]	4.00 (2.33) [3.10]	0.00 (0.83) [0.90]	2.33 (1.85) [4.71]	0.00 (1.38) [1.43]
MRS of:	**Distance for Depth**	**Distance for Quarrels**	**Distance for Depth**	**Distance for Quarrels**	**Distance for Depth**	**Distance for Quarrels**
Cooking	0.00 (0.30) [1.73]	2.33 (0.56) [1.82]	1.00 (0.40) [0.71]	0.00 (0.60) [1.86]	1.13 (1.67) [1.16]	0.38 (1.50) [1.84]
Utensil Washing	0.00 (0.23) [1.86]	2.33 (0.43) [1.90]	0.22 (0.00) [0.17]	0.34 (0.67) [0.50]	1.13 (1.67) [1.24]	0.38 (1.50) [1.76]
Clothes Washing	0.00 (0.25) [1.64]	2.33 (0.54) [1.91]	0.57 (0.67) [0.17]	0.81 (1.11) [0.41]	1.35 (1.67) [1.00]	0.59 (1.50) [2.00]
Women's Bathing	0.00 (0.38) [1.86]	2.33 (0.54) [1.90]	1.50 (0.67) [1.00]	0.00 (1.11) [1.33]	1.92 (1.67) [1.17]	1.25 (1.50) [2.17]
Girl's Bathing	0.00 (0.42) [1.08]	2.33 (0.50) [2.08]	1.50 (0.50) [1.45]	0.00 (1.00) [2.09]	1.59 (1.20) [1.08]	0.35 (1.13) [2.08]
Boy's Bathing	0.00 (0.40) [1.36]	2.33 (0.60) [2.18]	1.92 (0.50) [1.46]	1.25 (1.00) [1.38]	2.00 (0.50) [0.88]	2.00 (1.00) [2.12]

Note: In each set of three numbers, the first (without parentheses or brackets) gives the MRS for the pre-monsoon season; the second (in parentheses) gives the MRS for the monsoon months; and the third figure (in brackets) gives the MRS for the post-monsoon months.

In the pre-monsoon period, the MRS of distance for quarrels is high for the poor and low for other groups. That is, the poor will travel substantial distances to avoid quarrels, whereas the medium and the rich will be little affected by quarrels in choosing their drinking water sources. In other words, during the non-monsoon months the results suggest that if rich and poor families have the same water sources available to them, the poor families tend to choose sources which are of worse quality but which are closer and at which quarrels are less likely.

During the monsoon, water sources become merged and ownership is characteristically more communal than private. During this period the effects of the different characteristics change: As was discussed with reference to Table 4, it is now the richer groups who are prepared to go greater distances to avoid quarrels.

Non-drinking water uses—In all cases in the pre-monsoon period the data show that the MRS of distance for depth increases uniformly as income increases. That is, in all cases, the rich are prepared to go further to get water of higher quality. During the monsoon period, with very few exceptions, this pattern holds true. During the post-monsoon period the data show no clear trend.

During the pre-monsoon period the MRS of distance for quarrels is uniformly highest for the poor, suggesting that the poor are most willing to travel further to avoid conflict. During the monsoon the MRS of distance for quarrels rises with income. That is, as in the case of drinking water this effect is, for the reasons discussed earlier, precisely the opposite of the effect in the pre-monsoon period.

SUMMARY AND CONCLUSIONS

The results show that, for drinking water, quality is a powerful determinant of the attractiveness of a water source, distance is not a powerful determinant for any of the income groups, and conflicts over access to drinking water sources adversely affect the choices exercised by the poor families. These results have important implications for programs for improving the quality of drinking water used in rural areas of Bangladesh. To date the large UNICEF/Government of Bangladesh water supply program has assumed that the most important factor governing the use of a drinking water source is the distance of the source from the home. These results imply that water supply programs should be somewhat less concerned with the distance of the improved source of water from the house, and more concerned with ensuring that these improved sources provide a quality of water which is perceived to be good by the users. The results also show that the ownership of a water source seriously affects the use of that source by different groups in the village, and suggest that, as the existing UNICEF program has done, public and communal sources should continue to be emphasized.

300 000 wells?

Except for the more wealthy families, water quality is of less importance for non-drinking uses that it is for drinking. For the poorer groups the most important factor in the relatively dry seasons is "quarrels". That is, the poor villagers are most likely to use water from those sources which they can use without the danger of being rebuked for doing so. This finding reinforces the earlier conclusion concerning the importance of ensuring that all groups will have access to the improved water sources which a national program might provide.

Several studies (Curlin *et al.*, 1975; Khan *et al.*, 1975; Levine *et al.*, 1976) on the effect of water use on cholera and other diarrheal diseases in rural Bangladesh have demonstrated that if the only effect of a water supply program is to induce people to drink water of a better quality, such a program is likely to have little effect on health. While the reasons for these findings are not clear (Briscoe, 1978), it appears that two other changes are necessary if water supply programs are to improve health. It is necessary that people use greater quantities of water for domestic purposes, and that better quality water is used for non-drinking purposes (especially bathing and cooking), too.

These findings strongly argue against a water supply program, like the existing UNICEF program, which is exclusively devoted to the installation of hand-pumped tubewells. Because the tubewell water is high in iron and turns rice black when it is used for cooking, no study family used a tubewell as the source for cooking water. Because pumping a tubewell is hard work, no one in the study area (including the investigators) used a tubewell rather than a surface water source for bathing. It is essential that the scope of the water supply program is broadened to consider technologies other than the hand-pumped tubewell.

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Importance of iron removal from tw. water

However, Table 3 shows cooking & bathing to be highly insensitive to change in parameter values, i.e. we cannot make one place more attractive than another by making it more accessible, by improving quality etc. i.e. any program for improving the characteristics of the type of source (e.g. deepening a protected pond & providing better access to it) would be unlikely to induce any behavioral change → have to accept that they will continue to use the sources actually used for cooking & bathing & try to improve water quality in these.