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Estimating water demand in developing countries

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Summary

When water supply systems are to be improved, planners usually assume that:

In urban areas, prices can be set to fully recover costs and that, at these prices, all potential consumers in the service area will connect to the new system and will use similar quantities of water to those already connected;

In rural areas, if systems are designed so that the monetary cost consumers does not exceed 5% of income, all families within the service area will choose to use the new system and will use water in quantities similar to those who currently, use such systems.

Numerous evaluations by the World Bank and others have shown that connection frequencies and consumption rates are quite different from those assumed, and that the economic and (particularly) financial consequences can be serious.

The paper outlines a World Bank research project (to be conducted over the next two years) which aims to improve understanding of water demand in urban and rural areas. In particular, the following will be addressed:

Present design practices and the consequences;
Research on water demand in developing countries;
Design of the World Bank research project, including;
Theoretical framework;
Data to be collected;
Site selection;
Estimation techniques;
Outputs.

1. WATER CONSERVATION AND WATER DEMAND

The focus of most of the papers presented at this symposium has been on water conservation. In these papers much attention is paid to the technical possibilities inherent in the use of water-saving devices (such as low-volume flush toilets). As discussed throughout the Symposium, however, there is much uncertainty about the response of consumers to these devices. A central question in this debate is whether the benefit to the consumer (in terms of reduced water bills) will outweight the cost which the consumer associates with adoption of the new technology.

An essential element in encouraging consumers to consider these and other conservation options is to manipulate the price which is charged for water, ideally increasing the price to the point where the price paid for a liter of water is the cost incurred in producing one more liter of water. Because acceptance of such a philosophy invariably implies substantial increases in the price of water, this has obvious consequences for the engineering design of a system. For example, extrapolating past trends (when water prices were low) would almost certainly overestimate the true demand for water, leading to oversized systems.

In short, then, it is essential that a strategy for water conservation must include not only "supply considerations" (such as the development and marketing of improved water-using devices), but must also include attention to "demand factors" (which indicate how a variety of factors, including price of water, affect the likelihood that a particular water system will be used, and the quantities of water which will be drawn from the system).

This relative neglect of demand issues is not a feature only of discussions on water conservation, but permeates the whole field of water supply planning. In this paper we describe a research project, initiated by the World Bank, which aims to:

... develop a practical method for estimating demand for water in rural and urban areas of developing countries, and develop a coherent empirical data base on the effect of different factors (including price) on demand;

... assess the consequences of such information for the engineering and financial design of water projects.

2. BACKGROUND

The behavioral assumptions incorporated into the design of water supply projects are simple. In urban areas a "requirements" approach (implicitly assuming zero price and income elasticity of demand) is generally followed; in rural areas it is assumed that, so long as financial requirements do not exceed 5% of income, rural consumers will choose to abandon their existing water supply in favour of an "improved" system.

Several reviews by the World Bank (1,2,3), bilateral donors (4-8) and water supply agencies in developing countries (including some of the better agencies such as those of Sao Paulo (9) and Bogota (10)) have shown that these simple assumptions of behavioral responses to improved water supplies have usually proved to be incorrect. Specifically, in urban areas connection frequencies, water production and revenues have all been consistently much lower than those foreseen at appraisal (3), while in rural areas many of those "served" have chosen to continue with traditional practices for a variety of reasons (sometimes because the new service is not regarded as an improvement over the old, sometimes because the new service is too costly).

Use of incorrect demand information can affect project design adversely in a variety of ways. The engineering decisions affected are: the choice of technology and level of service, and the timing and scale of capacity expansions. The financial consequences of poor information on demand include: In urban areas, large shortfalls in revenues and inability of water supply agencies to reach cost-recovery targets; in rural areas, revenues for even operation and maintenance are not generated and the systems fall into disrepair. Overall, the sustainability and replicability of investments in the sector are seriously compromised.

While poor performance in the sector is not the result of a single factor, in both urban and rural settings a major impediment to improved performance is inadequate information on the response of consumers to new options. Specifically what is required is a validated, practical methodology for assessing the response (in terms of connection frequency and quantities of water demanded) of consumers to different levels of service offered at different prices (including both connection fees and recurrent charges)*.

The World Bank, together with other external financing agencies and water supply agencies in several developing countries (including Brazil) has therefore initiated a research project, the objectives of which are:

1. To develop a coherent theoretical basis for assessing water demand in developing countries;
2. To assess, initially in five settings in each of three countries, the effects of water source and family characteristics on the probability that a family will choose to use a new source, and on the quantity of water the family is likely to draw from the new source;
3. To provide a validated method which can be used in project preparation procedures for collecting demand information;
4. To explore the prospects of rapid demand surveys (using small samples, in which limited information is collected and in which simple analyses are performed) which may be appropriate for routine use in identifying and preparing projects.

3. PREVIOUS RESEARCH ON WATER DEMAND

There is a large literature on water demand in developed countries, with most studies being conducted in the United States and most of these studies pertaining to single-family residences (11). By and large these are single equation models estimated by standard techniques, with the focus being on the estimation of income and price elasticities of demand. The key methodological issues addressed in this literature include: the consequences of using cross-sectional, time series or pooled data (12); the effects of using aggregate data (13); the specification of price variables (average, marginal or a more complex price variable) (14,15); the effects of water-using devices (16); the definition of the dependent variables (average annual, maximum day, peak hour) (13); specifications and estimation techniques to overcome violations of the assumptions of Ordinary Least Squares (17).

The substantial literature on water demand in industrialized countries is relevant to the proposed research project in several ways.

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First, because of the preponderance of such studies in the literature, the robust results of such studies (such as the relatively low price elasticity of demand) have come to be generally accepted as universally true. Second, the majority of investigations of water demand in developing countries have used this standard approach without major modification. And third, several of the methodological points which are of concern in industrialized countries (such as the definition of the price variable in such models) are relevant to water demand in developing countries, too.

It is argued here, however, that the questions of interest in most developing country settings are radically different from those of interest to planners in industrialized countries, and that the uncritical adoption of the methods and results of studies in industrialied countries has been a serious error. The core of this argument is that the characteristics of a water supply are quite different in industrialized countries and in many settings in developing countries. These differences are most easily perceived if one compares standard water supply projects in a US city, and an Brazilian village.

Nature of the commodity: In a European city there is just one source of water; in an Brazilian village there are several sources, each with different characteristics (perceived quality, reliability, distance, and price). In standard industrialized-country water demand theory, water is (correctly) treated as a homogeneous good; in the Brazilian village water is a heterogeneous good, with each source providing water with a different set of characteristics. Models describing water choices in the Brazilian village must take account of the heterogeneous nature of water in this setting.

Choice of water source: In a US city there is a single standard level of service (multiple taps in the house), whereas in the Brazilian village there is a wide range of options -- house connections, yard taps, standposts, use of traditional sources, etc. -- facing both suppliers and consumers. Accordingly, whereas the choice of water source does not exist in the US city, in the Brazilian village the first element of a water behavior model must be a description of the likelihood, under different conditions, that a consumer would choose to use an "improved" source rather than continue to use the existing source.

Quantities demanded: In a US city a "demand model" is a description of the effects of different factors (such as price and income) on the quantity of water used. This demand equation is correctly estimated by standard regression techniques. In the Brazilian village the decision on the quantity of water used is made simultaneously with the decision on the source to be used. Because of this simultaneity, the model describing the quantity of water used must be estimated jointly with the model describing the source choice. Accordingly this is a more complex model, now involving a simultaneous discrete/continuous choice.

Different end uses: In US cities it has been found that the price and income elasticities are markedly different for in-house and sprinkler use. Accordingly it is now standard practice, where such data are available, to estimate two independent demand functions. In the Brazilian village there are several distinct water-using activities. When an improved source is introduced, even where a family uses the new source, the traditional source will often continue to be used for some activities. Because in such settings the effects of a variety of source and family characteristics are quite different depending on the end use of the water (18), it is necessary to take account of which specific activities are being carried out at the improved source when estimating the demand for water from that source.

Data available: In demand analyses in the US, analysts use data on water usage obtained from the records which the utility maintains for billing purposes. This is sensible for two reasons: because it is relatively easy and cheap to obtain such data; and because the questions which will be asked of the demand analyses (such as slight price increases) do not require extrapolation far beyond the range of existing data. In the Brazilian village the situation is quite different. First, it is a laborious and difficult job to collect valid information on actual uses of water. And, second, the project will often introduce a type of service which has not previously existed in the village, with consequent difficulties in extrapolating beyond the range of the data. The use of methods which construct hypothetical markets are therefore more interesting in the Brazilian village than in the US city. For these reasons, although contingent valuation techniques have not been used in estimating the demand for water in industrialized countries, there have been some preliminary efforts (1,19,20) at use of this technique in developing countries.

4. CURRENT DESIGN PRACTICE

An initial phase of this research project involved a detailed review of project preparation and evaluation documents from the World Bank, the Inter-American Development Bank (IDB) and the United States' gency for International Development (USAID), the purpose being to assess how demand considerations are incorporated into project planning, and what lessons can be drawn from ex post evaluations.

A number of World Bank, and all recent IDB, urban water projects have attempted to incorporate demand considerations into project planning. The methodology of these studies has been directly drawn from the industrialized country literature, with the focus being on the estimation of income and price elasticities from single equation demand models. In the case of the extensive set of IDB demand studies -- all IDB projects prepared since 1977 have included a demand study -- the methodology has been similar and the purpose primarily the estimation of willingness to pay and thus project benefits.

These demand studies provide some tentative confirmation that water demand in developing countries is, indeed, different from that in developed countries. For instance, the studies suggest that price and income elasticities of demand are somewhat greater in developing countries than in developed countries.

Although these demand studies have been useful for some purposes, World Bank reviews have indicated that "information on water demand patterns in developing countries is sketchy, (with) little cross-country analysis undertaken" (21) and "the question of how very low-income households would respond to a price increase has not been carefully explored" (22).

Unsatisfactory as the situation in urban settings is, the situation with respect to information on demand in rural areas is even worse. The standard design assumption is that rural people should be provided with the highest level of service that requires them to pay less than 3% to 5% of income for the supply. A series of illuminating evaluations of USAID-funded rural water supply projects (23-29) has shown this assumption to be a primary factor in poor utilization of improved water supplies in rural areas. To take but one example, in rural Thailand it was shown (23) that villagers were unwilling to pay small amounts for the maintenance of "affordable" handpump or standpipe supplies, but that they were willing to, and did, pay large amounts for "unaffordable" yard taps.

5. RESEARCH DESIGN

In the planned research project two different approaches will be used to describe the demand for water. First, data on the actual choices (regarding, for instance, whether they should connect to the public system and, if so, whether they should install a yard tap or house connection) can be collected and from these data inferences drawn concerning the determinants of these choices. A, second, quite different approach is to ask potential consumers how much they are willing to pay for different types and levels of service and, from these hypothetical data, to draw inferences on the determinants of behavior. Details of the methods which may be used for each of these approaches are presented elsewhere (30); here we discuss the advantages and disadvantages of each approach.

The procedure of basing the model on observed behavior has one great advantage, viz. the results are credible because data are drawn from actual practices. There are, however, also disadvantages, which include:
(i) In many instances a demand study will be done to predict behavioral responses (connection frequencies and quantities drawn) to presently-unavailable levels of water supply service. Where this is the case estimates based on actual behavior require extrapolation of the findings beyond the range covered by the data, a dangerous practice.
(ii) In many situations there appears to be a substantial discrepancy between the revealed value of a commodity, and the payments which a family will actually make for an improvement in the commodity. In part this is probably because an individual's assessment of what is "reasonable to pay" for a commodity is influenced not only by the intrinsic value of the commodity but also by what is customarily paid by those who have such a service (33). Where this is the case, the revealed "willingness to pay" would overestimate the payments which would actually be forthcoming for the improved service. There is some empirical evidence that this may often be the case in the water sector (1). Where financial considerations (such as cost recovery) rather than economic considerations (such as optimal resource allocation) are at issue -- as they often are in this sector -- then it is information on the actual payments that would be made which is of primary interest. In such a situation inferences from practice may not give useful answers.
(iii) This procedure is consistent with a "top-down" approach to water supply planning, in which the task of the planner is to plan correctly without necessarily involving the community in the planning process. While this may be appropriate in urban areas, an essential component of successful rural water supply projects (e.g. Malawi (31) and Colombia (32)) has been involvement of the community in the development of the project.

With regard to the willingness-to-pay (also known as "contingent valuation") approach, the major, obvious, drawback of using hypothetical questions is that the answers to such questions may not be true. Drawing on a decade of experience with willingness to pay questions in assessing environmental improvements in the United States (33), however, there are now well-established methods for limiting the biases arising in such investigations and for determining the likely magnitude of such biases. A preliminary field trial of the method in rural Haiti tentatively suggests this method can be used for assessing willingness to pay for improved water supplies without being subject to large biases. If upon further testing the method does prove to be valid, then there are substantial advantages to the approach. These include the following:
(i) Where concern is with financial aspects (such as actual payments that will be made), then the method should give a measure of the payments which will actually be made, not the implicit benefits of the service. The willingness-to-pay approach is more appropriate than the "revealed"

approach in this regard, for, in a correctly-conducted willingness-to-pay survey relevant factors such as perceptions about "reasonable rates" would implicitly be taken into account.
(ii) With the willingness-to-pay approach consideration can be given to levels and services and charges which presently do not exist in the community;
(iii) The method requires that active community involvement in choice of the water service to be provided takes place.

While the primary research appraoch will thus be an economic one, in each country focussed anthropological enquiries will supplement the household-level economic surveys. Prior to the initiation of the household surveys the antrhopological work will focus on issues relevant to sample choice (such as definition of decision-making units) and questionnaire design (such as meaningful bidding schemes). After conduct of the household surveys the anthropological work will focus on key issues emerging from the preliminary data analysis (such as reasons for the particular parameter values, and reasons for the divergence between the estimates emerging from the indirect and direct methods).

6. SUMMARY AND CONCLUSIONS

In this paper we have suggested that for the effectiveness of investments in the water supply sector to be improved, more attention needs to be given to demand issues. The paper outlines a research project on water demand which will be conducted in Brazil and other countries and which will produce:

... Country-specific studies of water demand;
... A multi-country comparative analysis of water demand;
... Guidelines for designing, conducting and analyzing data on water demand for project planning purposes.

These reports are expected to be of direct use to planners in the study countries and elsewhere, and to constitute major inputs into a policy analysis (being planned by the World Bank) concerning water supply project and sector choices (such as technology choice, project scale and timing, tariff levels and subsidy mechanisms and levels) that should be influenced by considerations of water demand.

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ESTIMATING WATER DEMAND IN DEVELOPING COUNTRIES

by

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The substantial literature on water demand in industrialized countries is relevant to the proposed research project in several ways. First, because of the preponderance of such studies in the literature, the robust results of such studies (such as the relatively low price elasticity of demand) have come to be generally accepted as universally true. Second, the majority of investigations of water demand in developing countries have used this standard approach without major modification. And third, several of the methodological points which are of concern in industrialized countries (such as the definition of the price variable in such models) are relevant to water demand in developing countries, too.

It is argued here, however, that the questions of interest in most developing country settings are radically different from those of interest to planners in industrialized countries, and that the uncritical adoption of the methods and results of studies in industrialied countries has been a serious error. The core of this argument is that the characteristics of a water supply are quite different in industrialized countries and in many settings in developing countries. These differences are most easily perceived if one compares standard water supply projects in a US city, and an Brazilian village.

Nature of the commodity: In a European city there is just one source of water; in an Brazilian village there are several sources, each with different characteristics (perceived quality, reliability, distance, and price). In standard industrialized-country water demand theory, water is (correctly) treated as a homogeneous good; in the Brazilian village water is a heterogeneous good, with each source providing water with a different set of characteristics. Models describing water choices in the Brazilian village must take account of the heterogeneous nature of water in this setting.

Choice of water source: In a US city there is a single standard level of service (multiple taps in the house), whereas in the Brazilian village there is a wide range of options -- house connections, yard taps, standposts, use of traditional sources, etc. -- facing both suppliers and consumers. Accordingly, whereas the choice of water source does not exist in the US city, in the Brazilian village the first element of a

water behavior model must be a description of the likelihood, under different conditions, that a consumer would choose to use an "improved" source rather than continue to use the existing source.

Quantities demanded: In a US city a "demand model" is a description of the effects of different factors (such as price and income) on the quantity of water used. This demand equation is correctly estimated by standard regression techniques. In the Brazilian village the decision on the quantity of water used is made simultaneously with the decision on the source to be used. Because of this simultaneity, the model describing the quantity of water used must be estimated jointly with the model describing the source choice. Accordingly this is a more complex model, now involving a simultaneous discrete/continuous choice.

Different end uses: In US cities it has been found that the price and income elasticities are markedly different for in-house and sprinkler use. Accordingly it is now standard practice, where such data are available, to estimate two independent demand functions. In the Brazilian village there are several distinct water-using activities. When an improved source is introduced, even where a family uses the new source, the traditional source will often continue to be used for some activities. Because in such settings the effects of a variety of source and family characteristics are quite different depending on the end use of the water (18), it is necessary to take account of which specific activities are being carried out at the improved source when estimating the demand for water from that source.

Data available: In demand analyses in the US, analysts use data on water usage obtained from the records which the utility maintains for billing purposes. This is sensible for two reasons: because it is relatively easy and cheap to obtain such data; and because the questions which will be asked of the demand analyses (such as slight price increases) do not require extrapolation far beyond the range of existing data. In the Brazilian village the situation is quite different. First, it is a laborious and difficult job to collect valid information on actual uses of water. And, second, the project will often introduce a type of service which has not previously existed in the village, with consequent difficulties in extrapolating beyond the range of the data. The use of methods which construct hypothetical markets are therefore more interesting in the Brazilian village than in the US city. For these reasons, although contingent valuation techniques have not been used in estimating the demand for water in industrialized countries, there have been some preliminary efforts (1,19,20) at use of this technique in developing countries.

4. CURRENT DESIGN PRACTICE

An initial phase of this research project involved a detailed review of project preparation and evaluation documents from the World Bank, the Inter-American Development Bank (IDB) and the United States' gency for International Development (USAID), the purpose being to assess how demand considerations are incorporated into project planning, and what lessons can be drawn from ex post evaluations.

A number of World Bank, and all recent IDB, urban water projects have attempted to incorporate demand considerations into project planning. The methodology of these studies has been directly drawn from the industrialized country literature, with the focus being on the estimation of income and price elasticities from single equation demand models. In the case of the extensive set of IDB demand studies -- all IDB projects prepared since 1977 have included a demand study -- the methodology has been similar and the purpose primarily the estimation of willingness to pay and thus project benefits.

These demand studies provide some tentative confirmation that water demand in developing countries is, indeed, different from that in developed countries. For instance, the studies suggest that price and income elasticities of demand are somewhat greater in developing countries than in developed countries.

Although these demand studies have been useful for some purposes, World Bank reviews have indicated that "information on water demand patterns in developing countries is sketchy, (with) little cross-country analysis undertaken" (21) and "the question of how very low-income households would respond to a price increase has not been carefully explored" (22).

Unsatisfactory as the situation in urban settings is, the situation with respect to information on demand in rural areas is even worse. The standard design assumption is that rural people should be provided with the highest level of service that requires them to pay less than 3% to 5% of income for the supply. A series of illuminating evaluations of USAID-funded rural water supply projects (23-29) has shown this assumption to be a primary factor in poor utilization of improved water supplies in rural areas. To take but one example, in rural Thailand it was shown (23) that villagers were unwilling to pay small amounts for the maintenance of "affordable" handpump or standpipe supplies, but that they were willing to, and did, pay large amounts for "unaffordable" yard taps.

5. RESEARCH DESIGN

In the planned research project two different approaches will be used to describe the demand for water. First, data on the actual choices (regarding, for instance, whether they should connect to the public system and, if so, whether they should install a yard tap or house connection) can be collected and from these data inferences drawn concerning the determinants of these choices. A, second, quite different approach is to ask potential consumers how much they are willing to pay for different types and levels of service and, from these hypothetical data, to draw inferences on the determinants of behavior. Details of the methods which may be used for each of these approaches are presented elsewhere (30); here we discuss the advantages and disadvantages of each approach.

The procedure of basing the model on observed behavior has one great advantage, viz. the results are credible because data are drawn from actual practices. There are, however, also disadvantages, which include:

(i) In many instances a demand study will be done to predict behavioral responses (connection frequencies and quantities drawn) to presently-unavailable levels of water supply service. Where this is the case estimates based on actual behavior require extrapolation of the findings beyond the range covered by the data, a dangerous practice.
(ii) In many situations there appears to be a substantial discrepancy between the revealed value of a commodity, and the payments which a family will actually make for an improvement in the commodity. In part this is probably because an individual's assessment of what is "reasonable to pay" for a commodity is influenced not only by the intrinsic value of the commodity but also by what is customarily paid by those who have such a service (33). Where this is the case, the revealed "willingness to pay" would overestimate the payments which would actually be forthcoming for the improved service. There is some empirical evidence that this may often be the case in the water sector (1). Where financial considerations (such as cost recovery) rather than economic considerations (such as optimal resource allocation) are at issue -- as they often are in this sector -- then it is information on the actual payments that would be made which is of primary interest. In such a situation inferences from practice may not give useful answers.
(iii) This procedure is consistent with a "top-down" approach to water supply planning, in which the task of the planner is to plan correctly without necessarily involving the community in the planning process. While this may be appropriate in urban areas, an essential component of successful rural water supply projects (e.g. Malawi (31) and Colombia (32)) has been involvement of the community in the development of the project.

With regard to the willingness-to-pay (also known as "contingent valuation") approach, the major, obvious, drawback of using hypothetical questions is that the answers to such questions may not be true. Drawing on a decade of experience with willingness to pay questions in assessing environmental improvements in the United States (33), however, there are now well-established methods for limiting the biases arising in such investigations and for determining the likely magnitude of such biases. A preliminary field trial of the method in rural Haiti tentatively suggests this method can be used for assessing willingness to pay for improved water supplies without being subject to large biases. If upon further testing the method does prove to be valid, then there are substantial advantages to the approach. These include the following:
(i) Where concern is with financial aspects (such as actual payments that will be made), then the method should give a measure of the payments which will actually be made, not the implicit benefits of the service. The willingness-to-pay approach is more appropriate than the "revealed" approach in this regard, for, in a correctly-conducted willingness-to-pay survey relevant factors such as perceptions about "reasonable rates" would implicitly be taken into account.
(ii) With the willingness-to-pay approach consideration can be given to levels and services and charges which presently do not exist in the community;
(iii) The method requires that active community involvement in choice of the water service to be provided takes place.

While the primary research appraoch will thus be an economic one, in each country focussed anthropological enquiries will supplement the household-level economic surveys. Prior to the initiation of the household surveys the antrhopological work will focus on issues relevant to sample choice (such as definition of decision-making units) and questionnaire design (such as meaningful bidding schemes). After conduct of the household surveys the anthropological work will focus on key issues emerging from the preliminary data analysis (such as reasons for the particular parameter values, and reasons for the divergence between the estimates emerging from the indirect and direct methods).

6. SUMMARY AND CONCLUSIONS

In this paper we have suggested that for the effectiveness of investments in the water supply sector to be improved, more attention needs to be given to demand issues. The paper outlines a research project on water demand which will be conducted in Brazil and other countries and which will produce:

... Country-specific studies of water demand;
... A multi-country comparative analysis of water demand;
... Guidelines for designing, conducting and analyzing data on water demand for project planning purposes.

These reports are expected to be of direct use to planners in the study countries and elsewhere, and to constitute major inputs into a policy analysis (being planned by the World Bank) concerning water supply project and sector choices (such as technology choice, project scale and timing, tariff levels and subsidy mechanisms and levels) that should be influenced by considerations of water demand.