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THE ECONOMIC BENEFITS OF POTABLE WATER SUPPLY PROJECTS TO
HOUSEHOLDS IN DEVELOPING COUNTRIES

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Abstract

In this report the authors argue that there is a need for both improved procedures and better practice in the estimation of the economic benefits of water supply projects. The authors discuss the concept of "economic benefits" in the water supply sector, and then present several approaches that can be used to estimate the economic benefits to households of potable water supply improvements. These include (1) procedures for calculating cost savings, (2) a procedure based on an assumed water demand function that can be used to estimate the consumer surplus associated with increased water consumption, (3) the contingent valuation method, and (4) the hedonic property value model. The selection of the appropriate approach to use in a given situation will depend on the time and budget constraints of the analyst doing the economic analysis. However, in general, all of the recommended approaches require at least some primary data collection at the household level. Household water demand behavior is sufficiently complex, and existing data on household water use are so limited that it is rarely advisable to rely solely on desk-top studies to estimate project benefits. Primary data collection (including household surveys) is necessary during project preparation and appraisal in order to improve the quality of benefit estimates.

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I. Introduction

By good luck or poor oversight, depending on one's perspective, water supply projects in developing countries have been largely spared from critical examination by economists. Generally speaking, neither donor agencies nor national governments look carefully at the economics of investments in urban or rural water supply projects. Water supply projects are rarely subjected to the kind of rigorous economic analysis that is expected in many other sectors.

This lack of economic appraisal of water projects has occurred for two basic reasons. First, in many cases improved water supplies are a very high priority for communities. People do not need it explained to them by professionals that, without water, they can only live for at most a few days. Both governments and opposition parties have often responded to this grassroots demand for improved water by asserting that (1) access to water is a basic human right, and (2) it is the government's responsibility to see that all citizens are supplied with clean, sufficient supplies of water. This philosophy was an integral part of the United Nations' International Drinking Water Supply and Sanitation Decade in the 1980s; it lives on in the slogan of the 1990 New Delhi Consultation on Safe Water and Sanitation: "some for all, rather than more for some."

The problem formulation implicit in this view is to minimize the costs of providing service to all, subject to the constraint that everyone is served at some minimal level. Because the planning problem has been defined as a matter of meeting basic needs and providing "coverage" to unserved populations, there would seem to be no need to estimate the benefits of water supply projects, because they have implicitly been assumed to be infinite. Such needs must be met regardless of the costs. To many professionals in this sector, efforts to look at the costs and benefits of water supply projects seem an unnecessary academic exercise, simply a hindrance to work that obviously needs to be done.

The second reason why economic analysis has been of limited use is that even if one were inclined to examine the costs and the benefits of water supply projects, the benefits of an improved water supply often prove difficult to measure. The exact nature of these difficulties is one of the topics examined in this paper, but it is enough here to note, by way of introduction, that the problems of measuring the health effects and other consequences of improved water supplies (such as the value of time women save by not having to carry water) have appeared intractable to many professionals in the sector.

These two realities—that governments and donor organizations have defined water as a basic right, and that it is difficult to value the benefits of improved water supplies in both physical and monetary terms (particularly the health benefits)—have contributed to a sector culture in which attempts at systematically analyzing the economic consequences of investment projects are viewed with suspicion, if not outright hostility, by many project officers and sector "policy analysts." In fact, not only is economic analysis avoided, but so are most attempts at rigorously evaluating the outcomes of investments in water supply projects (Whittington and Choe 1992).

For example, for the great majority of recent World Bank-financed water supply projects, no attempt was made to estimate the economic benefits of the investment (Lovei 1992). For urban projects, the standard practice is to carry out a financial analysis in which the "benefits" of the project are the revenues from water sales. Even though water prices are often subsidized for social reasons, financial rates of return on water projects are typically

low, and projects must be justified on other grounds. For rural water supply projects the World Bank almost never attempts to estimate economic benefits but instead alludes to "unquantifiable" benefits to justify projects. Similarly, the United States Agency for International Development makes no effort to estimate the economic benefits of water supply investments, nor does it have any guidelines or standard procedures for the economic appraisal of water supply projects. The Inter-American Development Bank (IDB) is the only major multilateral donor that regularly attempts to estimate the economic benefits resulting from its water supply projects (Powers 1978; Powers and Valencia 1980).

If the informal approaches to appraisal of water supply projects that are currently in use in most donor agencies were generally successful, then perhaps one could argue that there is little to be gained by better economic analysis. Sadly, this is not the case. For a variety of reasons, many water schemes do not live up to expectations. In urban areas water projects often fail to achieve the performance anticipated in terms of water sales, number of connections, and the proportion of the costs recovered (World Bank 1992). In rural areas many people supposedly "served" by new water facilities have chosen not to use these facilities and have, instead, continued to rely on traditional sources.

Different disciplines have offered various explanations for the lack of success of so many water supply investments. Public health professionals cite people's lack of knowledge of the health benefits of improved water supplies. Financial analysts doubt whether proposed tariffs are affordable. Anthropologists contend that project failure arises from donors' and central government planners' insensitivity to local customs and beliefs. Engineers point to a lack of technical expertise and an inability to operate and maintain water systems once they are in place. Many people believe that the lack of community participation and local involvement in design and management is a major cause of project failure.

Recently, economists and others have argued that one of the principal problems in the sector is the lack of sound economic analysis prior to project design and construction (Whittington, Briscoe, Mu, and Barron 1990; Briscoe, de Castro, Griffin, North, and Olsen 1990; Mu, Whittington, and Briscoe 1990, World Bank Water Demand Research Team 1993). Specifically, the projects selected must be those that people do want and are willing to pay for. The conventional wisdom has been that since everyone "needs" an improved water supply, central governments and donors cannot really make a mistake in selecting a site for a new water supply project. This reasoning, however, neglects two important facts. First, investment funds are limited, and even if all potential projects could pass a cost-benefit test, one should still try to allocate investments to the places where net benefits are greatest. Second, investment projects require that decisions be made not only on location, but also on the level of service to be provided and on the price(s) to be charged. Sometimes overly ambitious, "high technology" solutions to problems are proposed and implemented when simpler, low-cost alternatives would have been more appropriate. But it also happens that "low tech" solutions are provided when people desire a higher level of service. In both cases the technology selected is inappropriate, and soon the facilities are underutilized. Such projects are not sustainable or replicable and are thus a poor use of resources.

A. An Example from East Java

To determine whether residential customers were willing to pay the tariffs proposed for water supply improvements, consultants for the East Java Water Tariff Study (Knight and Scott Consultants 1985) surveyed approximately 1,500 households in two large towns

and eight villages in different parts of a World Bank project area in East Java. The proposed project called for the construction of piped water systems with public taps throughout the rural areas of East Java. The results of the consultants' survey showed, however, that the demand for water from public taps was much less than anticipated. Most of the rural households relied on skillfully constructed shallow wells for their domestic water supply, and almost 100 percent of the sample households said that they boiled their drinking water. The proposed piped water schemes were thus not likely to result in significant, if any, health benefits. Moreover, in most communities the majority of the households surveyed said that they were satisfied with their existing sources of water.

The consultants concluded that households would not use a public tap if it were more than 20 to 30 meters away from the house, which was much closer than the design standard then in use. In villages that already had public taps in operation, the highest proportion of sample households found to be using the public taps was only about 20 percent. The consultants concluded that although water from the piped systems with public taps would be heavily subsidized, it was unlikely that many households would use the water from the "improved" water systems, and that such rural systems were not financially viable.

Despite their lack of interest in public taps, many people in the rural project areas expressed an interest in and were willing to pay for a private connection. In one area, 30 percent of the sample households wanted a private connection at the specified price; in a second area, 68 percent did; and in a third, 73 percent.

In urban areas, fewer than 10 percent of the sample households wanted public taps. In one of these areas not a single household interviewed said that its members used public taps, which at the time had been in operation for six months. But about 75 percent expressed a desire for a private connection, even though the traditional affordability analysis (that households can spend 3 to 5 percent of their income for water) indicated that private connections were too expensive for the majority of households.

The consultants' study thus revealed that the proposed project design was flawed in two important respects. Project designers had assumed that households in rural areas would pay the subsidized tariff rates proposed, when in fact the majority probably would not. If a piped water system with public taps were installed in a typical village, most households would probably have continued to use their traditional water sources. Second, project designers had assumed that people would pay for public taps in urban areas, whereas in fact the demand for public taps was very low because households actually wanted and were willing to pay for private connections.

This example from East Java shows that careful economic analysis of water projects can lead to greatly improved decisions on choice of service level.

B. A Simple Classification Scheme

Assuming for a moment that it is possible to estimate the economic benefits of a water project, consider the four situations outlined in Table 1.1. The benefits of a water supply project may be either low or high; so may the costs. A two-by-two matrix illustrates the four possible cases that may result. One would obviously try to avoid Case C (low benefits, high costs). Yet if the assumption is that one cannot make a mistake on site selection, then donors and central water agencies will not necessarily attempt to identify such situations before investments have been made. Indeed, there is ample evidence from around the world that investments have been and are being made in such places.

TABLE 1.1
Costs and Benefits of Water Supply Systems:
A Simple Classification Scheme

Costs of the Water Project are:	Benefits of the Water Project are:	
	Low	High
Low	Case A	Case B
High	Case C	Case D

Investments are most desirable in Case B situations (high benefits, low costs). Most of these are found in urban areas; one does not find very many of these situations in rural areas (Whittington and Choe 1992). If the costs of water supply are low and the benefits are high, in many instances people will already have solved their water problem. Where Case B situations are encountered, it often happens that supply has been artificially constrained by rent-extracting agents (Lovei and Whittington 1993), in which case solutions to the water problem are likely to be more political than technical in character. In rapidly growing urban areas, the benefits of reliable, high-quality water service can be extremely high even in the absence of rent-seeking agents because the public water systems agencies have typically been unable to keep up with increases in demand.

Case A situations (low benefits, low costs) may occur in rural areas where traditional water supplies are plentiful and where the opportunity cost of time spent collecting water is low. The benefits of improved water supplies may, indeed, be positive in such situations, but the net benefits are not likely to be great. Investment in such areas will probably not yield the highest returns.

Case D situations (high benefits, high costs) are common in arid areas. Here the benefits are high for two reasons. First, because water is scarce, household members must walk (or ride animals) long distances to collect water, or they must pay water vendors high prices to do this job for them. The time and energy savings from an improved water system near their home (or the cost savings from not having to purchase water from vendors) are thus large. Second, because water in such areas is expensive, people use less of it. An improved water system may result in increased water use, and substantial health benefits may occur from a reduction in water-washed diseases.

It is a relatively straightforward task to estimate the financial costs of improved water supply systems. Accurate distinctions between these four cases thus depend especially upon how well one can estimate the general magnitude of the benefits and any costs not associated with direct financial outlays (such as the opportunity cost of water to users not served). Whether it is important to be able to estimate the benefits depends upon whether there are, in fact, substantial numbers of communities in each of the four cells. If all unserved communities fell under Case B, then it would not be really necessary to be able to estimate the benefits of water supply projects. But in our view, they do not: that there are substantial numbers of communities in the other cells.

C. Overview

It is our belief that there is an urgent need for better estimates of the economic benefits of water supply projects. This paper offers practical advice and guidance on how such estimates can be prepared. We have focused on approaches for estimating the economic benefits to households of improved water supplies. (Methods for analyzing the economic costs of water supply projects are in most cases similar to those required for other kinds of development projects.) Chapter II discusses what is meant by the "economic benefits" of water supply projects and identifies some of the limitations of using the criterion of "economic efficiency" in appraising water supply projects. In Chapter III we continue our discussion of the meaning of "economic benefits," this time focusing on the perspective of the individual.

Chapters IV and V review the various approaches that are available for estimating the economic benefits of water supply projects and consider their strengths and weaknesses. In Chapter IV we discuss revealed preference (indirect) approaches for estimating economic benefits, and we present a simple procedure for developing approximations of benefits. (Appendix 1 includes a series of analytical expressions designed to assist water resource planners and engineers in making these calculations.) Chapter V discusses the use of contingent valuation surveys for collecting data on households' willingness to pay for improved water services and illustrates in some detail the various options for asking willingness-to-pay questions.

Chapter VI addresses the problem of how to estimate the time profile of benefits over the planning horizon. Chapter VII summarizes the procedures recommended in this paper and offers some concluding remarks. Appendix 2 presents guidelines for estimating the economic benefits of potable water supply projects.

II. Thinking about the Benefits of Improved Water Supplies

A. The Consequences of Water Supply Interventions

No community can exist without a source of water. Hence, a new water supply project is never the only water supply available. A new project simply changes the range of options available to households, commercial enterprises, and industries in the community. Such an intervention may increase the quantity of water available to a community, the reliability and convenience of the service provided, and (or) the quality of water available. These changes in quantity, reliability, convenience, and quality may range from modest to very significant. The economic value of a water supply project depends largely on the magnitude of these various changes relative to the existing situation.

Consider a case in which a new water project is built such that households can connect to the new distribution system via a metered private connection. (Let us assume that the reliability and quality of water from the existing source and from the new project are the same.) Heretofore, households have all depended on a few public handpumps that are maintained by the community at low cost. What is likely to happen as a result of the project?

It is, of course, possible that nothing will happen: households may decide not to connect to the new system. People may feel that water from a private connection is not worth the cost and that collecting water from the handpumps is not very burdensome. They

may have plenty of time available to fetch water and (as anthropologists sometimes argue) may enjoy the opportunity to socialize at the water source. In this case, there will be no economic benefits from the project, and the investment in it will be wasted. On the other hand, people may desire the private connections because they will no longer have to fetch water from the handpump and because they value the convenience of a private tap. If the value that they place on the time and effort they spend hauling water from the handpump and waiting in a queue is high, the real resource cost (or shadow price) of water to them—taking account of the value of their time—falls as a result of the project. And because the shadow price of water to households falls, the quantity of water they consume goes up. This sets in motion a sequence of changes in human behavior and economic activities in the community.

For example, women no longer have to spend time fetching water from the handpump. This time may now be reallocated to different activities, such as food preparation, agricultural work, child care, and leisure. (What such time savings would actually be used for in a particular community is an empirical question.) Moreover, the ready availability of water from a low-cost piped connection in the house may change personal hygiene habits, promoting increased bathing and clothes washing. If household water use rises significantly (as it almost always does when private connections are installed), the "real" value of a household's total expenditure on water, in terms of time, energy, and cash, may be greater than before, even though on a per unit basis water from the private connection is much less expensive than water from the handpumps.

These changes may manifest themselves in many ways, resulting in still further changes in human activities. The most commonly expected consequence of water supply interventions is improved human health. Increased water use for bathing, washing, and food preparation can often be expected to lead to a reduction in water-washed diseases. Improved water quality can be expected to reduce the incidence of waterborne diseases. Healthier people obviously live more enjoyable, satisfying lives. They also live more economically productive lives, experiencing fewer days of work lost to illness and spending less money on medical care.

Improvements in health may result from other causal mechanisms. If women have more time to spend on child care and food preparation, child mortality and morbidity may decline. Time savings reallocated to agricultural work may result in increased production and higher incomes, which may enable households to purchase better medical care.

Of course, only a small portion of any additional income resulting from time savings would likely be spent on improved medical care. The majority would support other consumption and investment preferences and lead to further changes in community economic activities. And changes in water use practices may be valued by households in and of themselves, for their aesthetic and quality-of-life aspects—that is, as a final consumer good.

Industries and commercial enterprises use water as an input in many activities, including manufacturing. A new water supply project may lower the cost of water to firms, thus lowering production costs. Large industrial facilities may use sufficient volumes of water to justify the investment necessary to self-supply themselves with water. Even so, the new public water supply project may provide water at lower cost and thus enable such firms to achieve some cost savings. The effects are most dramatic, however, on small businesses, for whom the costs of self-supplying are often prohibitive (Lee and Anas 1989). For example, a small bakery might not be able to afford its own well and pumping facilities. In such cases a water supply project may enable the creation of businesses that simply were not financially feasible before its construction.

Some of the changes that result from the introduction of a piped distribution system may be reflected in changes in the prices of other goods and services sold in the community; others may not. For example, the value of property accessible to the piped distribution system may increase (and property values near the public taps might decrease).

Some of the changes that result from the introduction of a piped distribution system may not be desirable. For example, increased household water use may increase the amount of sullage and sewage wastes, exacerbating wastewater disposal problems. Without sewerage and drainage facilities, the water project may create negative externalities (such as new public health problems) that affect everyone in the community, whether or not they decide to connect to the piped distribution system.

Our point here is that the provision of a new or improved piped water supply system will often have complex direct and indirect effects on many facets of households' lives and the community's economy. It is impossible to detail and classify them all: a community with a piped water supply system is a different kind of place than a community without piped water. On what basis can one judge whether the new situation is "better"? Or enough better to justify the costs of the project?

B. Valuing the Consequences of Water Supply Interventions

Water supply interventions can clearly result in changes in both human behavior and environmental conditions. Most people would consider that these changes should be assessed or measured in terms of several criteria or objectives, such as alleviation of poverty, improvements in human health and/or environmental quality, and "economic efficiency." A water project may be desirable in terms of all these criteria, or desirable in terms of some criteria and undesirable in terms of others (or even undesirable for all criteria). If, on balance, a project is judged to be desirable, it is often important that it be financially viable or sustainable so that, in fact, its effects can be realized. In this sense, financial feasibility can also be viewed as a criterion.

Our focus in this paper is on how to evaluate the consequences of water supply interventions in terms of the criterion of "economic efficiency." The terms "economic" and "efficiency" are widely used in everyday speech and have several different meanings. In the context of project appraisal, however, "economic efficiency" has a precise and often misunderstood meaning. The "economic efficiency" criterion is meant to measure individuals' "preference satisfaction," that is, how much different individuals value the various consequences that result from the project—in this case, the water supply intervention. Strictly speaking, it means how much people care about or desire the project's outputs. The use of the "economic efficiency" criterion thus requires that the project analyst attempt to measure the strength of individuals' preferences. The economic benefits of a project are defined as the summation of the affected individuals' preferences for it.

This definition is thus quite different from commonly held notions of the "economic benefits" of a water supply project. People typically think that "economic benefits" should be measured in terms of increased GNP or jobs created. Such changes in a community's economy are, of course, relevant to the question of how people value a water supply project, but they are indicators of changes in economic activity, not measures of "economic benefits" as defined by economists. It is entirely possible that a water supply project could result in large time savings that people chose to devote to leisure activities. If those leisure activities were highly valued by the people of the community, the economic benefits of the water

supply project would be high, even though people's money incomes remained unchanged and no jobs were created. This definition of "economic benefits" has important implications for the appraisal of water supply interventions. First, it means that the most appropriate measure of the value of the project's outputs is not the financial returns due, for example, to improved labor productivity from better health, or the value of increased agricultural income resulting from more labor inputs into agriculture. Rather, it is the household's increased utility or well-being that results from the water supply improvement. If a household feels that the best use of the time savings from not having to fetch water is increased leisure, this is by definition an economic benefit of the project—perhaps one of several desirable consequences of the new system that households discover or anticipate.

A second implication of this definition is that the project analyst does not actually have to know why an individual values a project, or even which of the many consequences or effects of the water project that an individual cares about most. It is enough to have a measure of the strength of the individual's preferences for the project; it is assumed that the individual knows his (or her) own interests and is the best judge of what the project is worth to him (or her).

The implementation of this concept of economic efficiency requires that individuals' preferences be measured in a common unit so that the preferences of different individuals can be compared and so that they can be aggregated into a single measure of the total "economic value" of the project. The conventional approach in the economics profession is to measure the strength of individuals' preferences in terms of how much of something else people will give up in order to obtain the project outputs. As a matter of convenience, this "something else" is almost always money. Thus, the value of the project outputs to individuals is usually measured in terms of the amount of money they would be willing to give up—that is, be willing to pay—to receive them.

The economic analysis of water supply interventions thus requires that the analyst try to measure the strength of individuals' preferences for the project in terms of how much individuals are willing to pay to receive the project outputs. From an economic point of view, the project is justified if the aggregate value of the project outputs, measured in terms of individuals' willingness to pay, is greater than the costs. The criteria of economic efficiency, improved health, and improved environmental quality are obviously not mutually exclusive, because individuals may see health and environmental improvements as among their reasons for being willing to pay a certain amount. The criterion of economic efficiency thus incorporates at least some of the value of the project's health, social, and environmental consequences to individuals as they themselves perceive them. On that basis it is incorrect to conceptualize the total benefits of the project as simply the summation of the economic benefits (as measured by individuals' willingness to pay), the health benefits, the social benefits, the poverty-alleviation benefits, and the environmental benefits.

There is, in fact, much unstated disagreement among professionals of different disciplines about the relative size of the health- and non-health-related benefits of water supply projects and about the extent to which individuals recognize or appreciate these benefits. Consider, for example, the hypothetical numbers in Table 2.1. Before the installation of a water project, individuals are assumed to perceive accurately only 70 percent of the total benefits of the water supply project. The majority of these perceived benefits are for non-health-related effects; only 10 percent of the total benefits are for health-related benefits of the project that are accurately perceived by individuals. Thirty percent of the total benefits of the project are not perceived at all; most of these are health-related benefits.

These percentages are simply hypothetical, but they do serve to highlight the interface between two sources of confusion and disagreement: (1) the relative size of the health- and the non-health-related benefits, and (2) the degree to which individuals accurately perceive the benefits of water supply projects. The numbers in Table 2.1 would obviously vary depending on the specific project being appraised. However, even for the same project, water sector professionals' prior expectations about the magnitudes of these values are often widely different. These differences are rarely discussed openly and investigated during the course of project appraisal, yet they are of great importance for developing an accurate estimate and an understanding of the total benefits of a water supply project.

C. Limitations of the Criterion of Economic Efficiency

There are several limitations to the criterion of economic efficiency as a sole basis for evaluating water supply projects. We classify the most important of these limitations into two broad categories: (1) questions regarding the ethical legitimacy of preferences for improved water supplies, and (2) the effect of income distribution on measures of willingness to pay for improved supplies.

1. Questions Regarding the Ethical Legitimacy of Preferences for Improved Water Supplies

The criterion of economic efficiency assumes that users' expressed preferences for improved water supplies should serve as a basis for planning and investment decisions. Professionals in the water supply sector often disagree with this basic assumption that underlies economic analysis. Consider the following three examples.

a. Ex-ante versus Ex-post Assessment of Preferences

In the analysis of the consequences of a project in terms of economic efficiency (that is, a cost-benefit analysis), benefits and costs are presumed to result from changes in states of the world in relation to an individual's fixed schedule of preferences. Yet many water projects seek to change households' water-use behavior as an explicit objective. Health educators and community organizers typically see themselves as agents of change and modernization. They often plan a "behavioral change program" to increase water use and improve hygiene practices. For example, they might promote the use of soap with hand-washing to reduce diarrheal diseases. Before the new project is constructed, households may, indeed, perceive the benefits of an improved water supply to be quite low; but after a behavioral change program and the installation of the new water system, people may realize that the benefits are much greater than they previously anticipated. Table 2.1 might look quite different if it recorded ex-post instead of ex-ante perceptions.

This poses several problems for any attempt to estimate the economic benefits of a water supply project. Suppose an improved water supply system is being appraised for a community in a developing country but that households in this community appear to be satisfied with their traditional water sources. Their willingness to pay for the proposed new water system is judged to be low, and, thus, on the basis of existing preferences, the project would not pass a cost-benefit test.

TABLE 2.1
Perceptions of Health- versus Non-Health-Related Benefits
of Water Supply Projects: Some Hypothetical Values

	Benefits of Water Supply Projects (%)		
	Health Related	Non-health-Related	Total
Proportion of the Benefits Individuals Recognize	10	60	70
Proportion of the Benefits Individuals Do Not Recognize	25	5	30
Total	35	65	100

But suppose that nearby there was another community that already had in operation an improved water system similar to that proposed for the first community. Before this water system was built, households in this second community were, by all appearances, very similar in cultural, religious, and socioeconomic characteristics to households in the first community. Now, after the water system has been in operation for a while, households in this second community value it highly. Water use has increased, and hygiene practices have improved. Households no longer use their traditional sources and are willing to pay substantial amounts for the operation and maintenance of their new water system. Would it be correct for the cost-benefit analyst to use the ex-post judgments of households in the second community to value the proposed water system in the first community?

A case can certainly be made for giving priority, under some conditions, to preferences predicted by such ex-post evaluation procedures. The basic reasons for doing so are that human well-being is not always the same as preference satisfaction and that judgments (or predictions) of this sort may measure human well-being better than ex-ante determinations of preferences (MacRae and Whittington 1988). Such problems require judgments that are outside the realm of standard cost-benefit techniques, and they demand careful thought.

b. Husbands' Views of Wives' Time Savings

A major benefit of improved water supplies is often the reduced time spent by household members hauling water from a source to the home. In most cultures, fetching water is a job for women (and often children). Thus, the provision of improved water supplies may have important implications for traditional social roles of men and women. If a woman whose time would be saved is married, her husband might consider a change in his wife's traditional role improper. He might disapprove not merely because of the potential change of power relations in the family, but also because the new "modern" roles and lifestyles seem to him to depart from a right and customary way of life. The husband's valuation of the consequences of the improved water supply must thus be negative, or at least diminished. How should the husband's preferences be treated in the course of project appraisal? Should they be ignored? Should the costs of the water project to the husband be subtracted from the benefits to the wife of not having to fetch water? Should they be weighted somehow to reflect the husband's mixed feelings about, for instance, benefits to his home business versus the prospect of domestic upheaval?

c. Households' Preferences for "Conspicuous Consumption"

Some households in a community may desire a house connection (rather than, say, access to a public tap) for "prestige reasons," or to impress their neighbors with their ability to pay for such a modern convenience. Water resource planners are often inclined to ignore such preferences for a higher level of service than the general population can afford, in effect judging them to be "illegitimate," perhaps because they seem inappropriate or unworthy. They thus assume that this demand for a "status good" is not a sound basis for the design of the water system. In such cases the strict application of cost-benefit principles (a criterion of economic efficiency) would lead to different investment conclusions than the "professional judgment" of the water resource planner.

Questions regarding what preferences are "illegitimate" (and should thus be excluded from a cost-benefit calculation) cannot be answered by the rigid application of standard economic principles. They require careful ethical consideration by professionals working in the water sector and others.

2. The Effect of Income Distribution on Measures of Households' Willingness to Pay for Improved Water Supplies

It is perhaps only stating the obvious to note that a household's willingness to pay for an improved water supply will depend in part on its income. Because a rich person can pay more for a desired good or service than a poor person, willingness-to-pay measures of preferences are conditioned on the income distribution of a community. The criterion of economic efficiency may thus be a poor indicator of the value or desirability of a project in terms of a criterion of poverty alleviation or social justice. (This limitation of cost-benefit analysis is true not only for its application to water projects but to other kinds of investments as well.)

Nevertheless, the significance of this limitation for the usefulness of the criterion of economic efficiency should not be overemphasized. Although the measurement of a household's economic benefits in terms of willingness to pay is conditioned on its income, income is not necessarily the only—or even the primary—determinant of willingness to pay (World Bank Water Demand Research Team 1993). Poor households without good alternative supplies are often willing to pay much more—in both absolute and relative terms—than richer families with good existing supplies.

The available evidence indicates that the percentage of its income that a household is willing to pay for use of an improved water source varies widely. For example, in the Chihota District in Zimbabwe, where water is relatively easily available from traditional wells, households are prepared to pay less than 0.5 percent of their income for an improved well with a handpump (Robinson 1988). In rural Haiti, households are willing to pay only about 1 percent of their income for access to public taps in their villages (Whittington, Briscoe, Mu, and Barron 1990).

In the sweetwater zones of the Punjab in Pakistan, almost every household has its own private handpump in its house or compound. These handpumps, manufactured by private-sector firms, have been installed and maintained without government involvement. Here, despite the relative prosperity of the villages, households are on average willing to pay only about 1 percent of their income for a private water connection (Altaf, Whittington, Jamal, and Smith 1993).

On the other hand, in some places households are willing to pay an extraordinarily high percentage of their income for improved water service. In the Newala District of Tanzania, households are extremely poor and spend several hours a day collecting water during the dry season. They are willing to pay about 8 percent of their meager income for access to water from public taps located in their village (Whittington, Mujwahuzi, McMahon, and Choe 1989). In Ukunda, Kenya, a small market town south of Mombasa, the majority of households are already spending more than 10 percent of their income purchasing water from water vendors (Whittington, Lauria, Okun, and Mu 1989). Fass (1988) found that during times of drought the poor in Port au Prince, Haiti sometimes pay more than 20 percent of their income to water vendors. Similar results have been found in Sudan (Cairncross and Kinnear undated), Honduras (Whittington, Lauria, Okun, and Mu 1989b), Mozambique (Katko 1990), Jakarta (Lovei and Whittington 1991), and Nigeria (Whittington, Okorafor, Okore, and McPhail 1990; Whittington, Lauria, and Mu 1991). It is thus clear that under some conditions people will pay a very high percentage of their income for water, and in other circumstances very little. Measures of household willingness to pay reflect much more than simply a household's income.

D. The Issue of Externalities and Estimates of Economic Benefits

Externalities occur when the consumption or production decisions of households or firms directly affect the consumption or production opportunities available to other firms or households, rather than through the price system. Both positive and negative externalities should be included in an estimate of the economic benefits of a project. Water projects are often justified on the basis of large positive "externalities." Community-wide health benefits are one of the most commonly cited positive externalities associated with potable water supply projects. An example of a negative externality would be the costs a household could impose on its neighbors by improper disposal of its wastewater.

The presence of externalities poses three related but conceptually distinct measurement issues for analysts attempting to estimate the benefits of potable water supply projects. The first is that such externalities may be hard to measure because they involve complicated causal relationships. For example, the relationship between the use of an improved water supply by one group of households in a community and the health benefits that accrue to other households that do not use the improved water supply is poorly understood by epidemiologists.

Second, externalities may be hard to measure because they may not be perceived by members of a household. An individual may not know that the use of an improved water source by his/her neighbors would benefit the members of his/her household. In this case the individual's behavior would not change as a result of the externality, and measurement techniques that rely on the "behavioral trail" of an individual or household will not be appropriate (see Chapter IV).

Third, if an individual does understand that the use of an improved water system by neighbors will benefit his/her household even if his/her household does not use the improved system, this household may have an incentive to understate its preferences for an improved system. This is known as the free rider problem. In general it arises when one household's consumption of a good (in this case improved public health conditions) does not affect the amount of the good available for others' consumption. In this case a household has an incentive to hide its preferences and to be a free rider in order to obtain the benefits

the new service (or public good) without paying its "fair share." The basic difficulty is simply that if one household takes an action that benefits other households and is not rewarded for it, then this household is unlikely to do enough of this action (or do it often enough).

For example, an individual household would probably obtain some health-related benefits from using an improved water supply, even if other households in the community did not. However, if all members of the community engaged in a collective decision to use the improved water source, then all might obtain an added benefit from a further reduction in the incidence of water-related diseases. In this case a positive externality would exist if

- (1) a household's decision to use an improved water supply resulted in health improvements for its members, and, as a result, they did not spread infectious diseases to other members of the community; and
- (2) if in making its decision as to whether to use the new water system, each household only valued the benefits of the improved water system to its own members, not to other members of the community.

This latter situation could arise, for example, if

- (1) a household did not perceive the benefits of its actions to its neighbors, or
- (2) a household did not take the benefits of its actions on its neighbors into account in its decision on whether to use the improved water supply because it was not rewarded for them (even if it did perceive such benefits).

In this paper we focus on measuring households' perceived benefits of potable water supply projects; we expect that the majority of the benefits a household perceives will be those that accrue to its members, not to other households in the community. This approach requires some explanation. There are several reasons why we recommend not relying too much on appeals to positive externalities to justify potable water supply projects.

First, some of the techniques detailed in this paper (e.g., the contingent valuation method, see Chapter V) probably do measure a portion of the perceived externalities of potable water projects. In this case externalities are not being ignored; they are included to some extent in the estimates of economic benefits. However, some externalities will be left out of such estimates.

Second, just the existence of positive externalities is not in itself a justification for a project: what matters is how large positive externalities are relative to other types of benefits and the project costs (including any negative externalities). In fact, we applaud rigorous attempts to measure positive and negative externalities associated with potable water supply projects, and believe that such estimates should be used in project appraisal. But just because the externalities associated with potable water supply projects are extremely difficult to measure, it should not be assumed that they are always large. This is particularly true when households do not perceive such benefits. In this case households may not use the improved water supply system and potential positive externalities may not materialize.

Often attempts to justify potable water supply projects on the basis of large, unquantified positive externalities are rather blatant attempts by project analysts to avoid careful scrutiny of the actual consequences of an intervention in the water supply sector. Unless defensible estimates of externalities can be developed, we believe that the prudent course in the economic appraisal of potable water supply projects is to avoid the use of benefit estimates based on unperceived externalities, and not to assume that households are acting as free riders. This will generally result in a conservative estimate of the total economic benefits; such a "lower bound" estimate of total benefits is often useful in terms of increasing one's confidence in the conclusions.

To illustrate these points, it is important to carefully distinguish the notion of health-related externalities from the health benefits that result from a water supply project. Table 2.2 details the four components of total health benefits to a single household resulting from the provision of a potable water supply project. The health benefits in cell A are those perceived by the household to accrue to its members from improved water services—regardless of the actions of other members of the community. The health benefits in cell B are those that the household perceives would accrue to its members if other households used the new system—even if its members do not. If the household judges that other households would use the improved water system, then the total health benefits that the household perceives are assumed to be $A + B$.

TABLE 2.2
Components of Health Benefits from an Improved Water Supply System

	Health Benefits that accrue to the members of an individual household if ...	
	(1) the household uses an improved water system and other households do not	(2) the household does not use an improved water system and other households do
Perceived Health Benefits	Cell A	Cell B
Health Benefits Not Perceived	Cell C	Cell D

The health benefits in cell C would accrue to the household if its members used the new system, but the household does not perceive these health benefits. The benefits in cell D would accrue to the household if other households used the improved system, but they are not perceived by the household. The health benefits in cells C and D are not properly termed "externalities" because they result from lack of knowledge, not from a failure of the price system to ensure that an agent (household) faces all of the consequences of its actions on the well-being of others. The benefits in cell A will be reflected in our estimates of economic benefits because they are perceived by the household and depend on the household's own actions. The health benefits in cells B and D are "externalities." The

benefits in cell B may be included in our estimates of economic benefits to the extent that an individual household feels an obligation or commitment to the good of the greater community. In other words, in order to receive the benefits in cell B, the household may feel a reciprocal obligation to provide such benefits to others.

In theory a household might attempt to free ride if it wished to avoid paying for the use of an improved water supply system, and still wished to receive the benefits in cell B without making any payment. In practice we do not believe that this is an important concern because households have a strong incentive to use an improved water supply system because they receive large private benefits (cell A).

In fact, it is likely that in many cultures households may be altruistic and receive value from knowing that other members of the community are benefiting from an improved water supply system—even if they do not. As with the benefits in Cell B, this is a positive externality that the household receives from actions taken by other households. This potential component of benefits is, however, not reflected in the classification scheme depicted in Table 2.2 because it is not properly classified as a "health benefit." Rather, it reflects the "satisfaction" or increase in "well-being" the household derives simply from knowing that other households are healthier.

E. Concluding Remarks

Despite the limitations of an "economic efficiency" criterion, the assessment of individuals' preferences in terms of their willingness to pay for water supply interventions can provide important information for decision makers on the advisability of a project. Such measures can indicate households' "strength of preference" for an improved water supply system—precisely the information a cost-benefit analyst must look for to estimate the economic benefits of the project. At the most basic level, preference satisfaction matters because projects should not be built that people do not want and will not use. Knowledge of the economic value of a project is important because most people would agree that resources should generally be allocated to projects that people want the most.

III. Thinking about the Economic Benefits of Improved Water Supplies: the Individual's Perspective¹

A. The Individual's Demand for Water: An Introduction

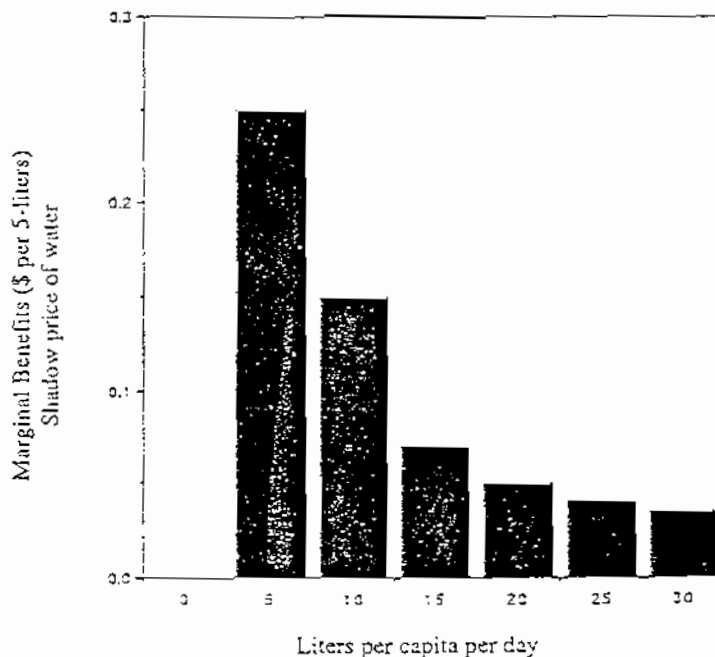
The value of water to an individual has been an enduring conundrum in the literature of economics. Nineteenth-century economists wondered how water, which was indispens-

¹ Throughout this chapter we refer to an individual's and a household's water use interchangeably. In effect, we postulate a household unit making decisions on its water source and the quantity of water to use. These two decisions result in an *average* water use for individuals in the household. In our exposition we discuss these individual averages because many readers will be most familiar with water use figures reported in this manner. We do not attempt to explain nor do we wish to infer anything about how water is allocated among members of the household or the intra-household politics of water source and quantity decisions.

able for life, could be free, whereas diamonds, which men and women could easily do without, were so expensive. This riddle was solved by noting the distinction between the total utility obtained from a good and the marginal utility derived from one additional unit of the good. The total utility that an individual derives from water is clearly infinite, because without a minimal amount of water a human being cannot exist. Once that basic need is satisfied, however, the marginal utility of additional water to the individual will be less (how much less is an empirical question).

Figure 3.1 illustrates this distinction. We assume that the first 5 liters of water per capita per day are what is required to sustain life and do not attempt to define the benefits to the individual from this quantity of water. Increasing the water available from 5 to 10 liters per day is extremely valuable to an individual: this additional water may permit the person to use water for cooking food and improving nutrition. Increasing the water from 10 to 15 liters per capita per day may permit additional cooking and some minimal washing. For each additional increment of water, the marginal value declines farther as the individual puts it to less and less valuable uses. In many parts of the United States residential water use may be as much as 700 liters per capita per day. The marginal value of additional water to such individuals is obviously very low. In fact, many such individuals probably could not think of a way to use additional water for household purposes, even if it were free; their demand for water is essentially satiated.

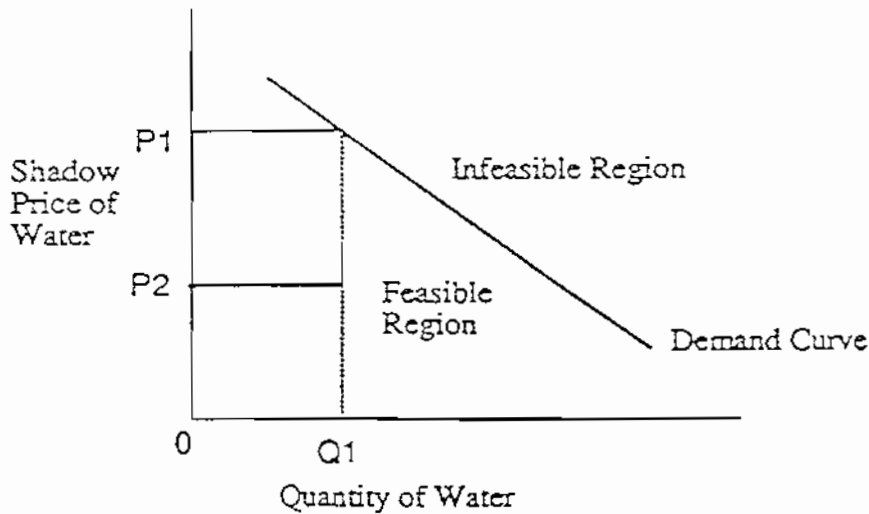
FIGURE 3.1
Marginal Benefits of Water vs. Quantity Used



This decline in the marginal value of additional water supplies as the quantity of water used increases can be described by the economist's standard downward-sloping demand curve (Figure 3.2). The vertical axis for "price" can be thought of as the marginal benefit of an additional unit of water or, alternatively, as the individual's "willingness to pay" (WTP)

for an additional unit of water.² The vertical axis may also be used to measure the shadow price, or real resource cost to the individual of obtaining water on a "per unit" basis. For example, the real cost per liter to an individual who must walk to a traditional water source to collect water would be the value of the time spent hauling water, times the amount of time spent, plus any cost of materials or equipment (such as rope and bucket) on a per trip basis, divided by the number of liters collected per trip. If a fee is charged for collecting water at the source, that money price must be added to the other costs. If water is instead delivered to the household, either by a piped system or by a water vendor, the vertical axis may represent the money price charged to the household for the water.

FIGURE 3.2
An Individual's (Household's) Water Demand Curve



In the discussion that follows, it is important to keep in mind that the notion of the "shadow price of water" used in defining a demand curve for water covers three possible cases: (i) there is no money price for water; the "price" variable reflects the real resource costs of collecting water from a traditional source; (ii) there is a money price charged for water at the source (for example, at a kiosk), but it is not the only cost incurred by the household in collecting water; the "shadow price of water" includes not only the money price but also the real resource costs of collecting water; and (iii) there is a money price, and it is the total cost to the individual of obtaining water. In each of these three cases, from a social point of view there may be an additional component to the "shadow price of water": the opportunity cost of any other competing user not having the water. For example, municipal water users may abstract their water supply from a river, thus leaving less water available downstream for irrigated agriculture. In such a case the shadow price of water to municipal users should include the resulting losses to agriculture. However, municipal users

² To be more precise, this WTP curve is an *uncompensated* demand curve. An individual's willingness to pay for the marginal unit is actually not likely to be independent of the price at which the intramarginal units of water are available because income effects could significantly affect relative values—particularly for poor households in developing countries.

will only take this opportunity cost into consideration if it is reflected in the water utility's pricing policy or if the property rights to the water are clearly assigned to agricultural users.

The demand curve for water can be thought of as dividing the price/quantity plane into two regions (Figure 3.2). Suppose an individual is consuming quantity Q_1 . The value to this individual of a very small increase in the quantity of water supplied is P_1 . If the real cost to this individual of this increase in water supply were less than P_1 , the individual would be willing to obtain (purchase) the additional water. For example, the individual would be happy to pay P_2 . Any point below P_1 is thus feasible; P_1 is the most the individual would be willing to pay per unit for the additional water. If the real cost to the individual was greater than P_1 , the individual would choose not to have this additional water. The region above the demand curve is thus infeasible in the sense that the individual is not willing to incur such costs (or pay this price).

It is useful to think about what determines the shape of the individual's demand curve for water. The individual's demand curve for water can be disaggregated into demand curves for different uses. For example, consider the individual's different demand curves for water for drinking and cooking, bathing and clothes washing, and irrigation for vegetable cultivation (Figure 3.3a). If the shadow price of water is high (say, P_1), the individual would only use a small amount of water (Q_1), all for drinking and cooking. If the shadow price of water falls to P_2 , more water will be used for drinking and cooking (Q_2), and water would also be used for bathing and washing (Q_3). If the shadow price of water falls below P_2 , the individual will begin to use water for garden irrigation.

The individual's aggregate demand curve for water is the horizontal summation of these three demand curves for specific water uses (Figure 3.3b). For example, the individual's total water use at P_2 would be $Q_1 + Q_2 + Q_3$ (though Q_3 would be zero at P_2). Because the marginal value of water to the individual is dependent upon its value in different uses, and because the marginal values for these separate uses may be very different, it is extremely unlikely that the horizontal summation of the individual's demand functions for different water uses will result in a linear aggregate demand curve for water (Tadler, 1990). As shown in Figure 3.3b, one would expect that an individual's aggregate demand function for water would be convex with respect to the origin, indicating that the marginal value of water does not decline at a uniform rate as water use increases. When water use is low, increases in use are associated with large declines in marginal value. At high levels of water use, increases are associated with smaller declines in marginal value.

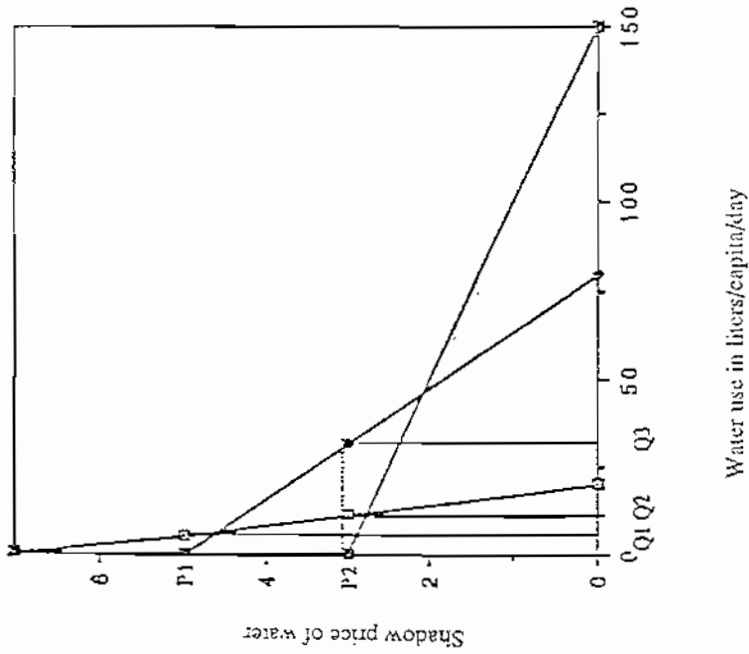
This horizontal summation of demand functions for different uses could easily result in an aggregate demand function that is discontinuous over a wide range of quantities of water use. For example, consider a household that is using water for irrigation of a large garden and for watering animals. If the price of water increases, one would expect that the household would use water more carefully and cut back somewhat on use. However, if the price of water continues to rise, at some point the household may stop using water for irrigation and animal watering altogether. If this occurs at a price of water that is still too low to discourage other household uses such as drinking and bathing uses, then the demand curve will be discontinuous at this price.

B. The Individual's Willingness to Pay for Water: The Standard Paradigm

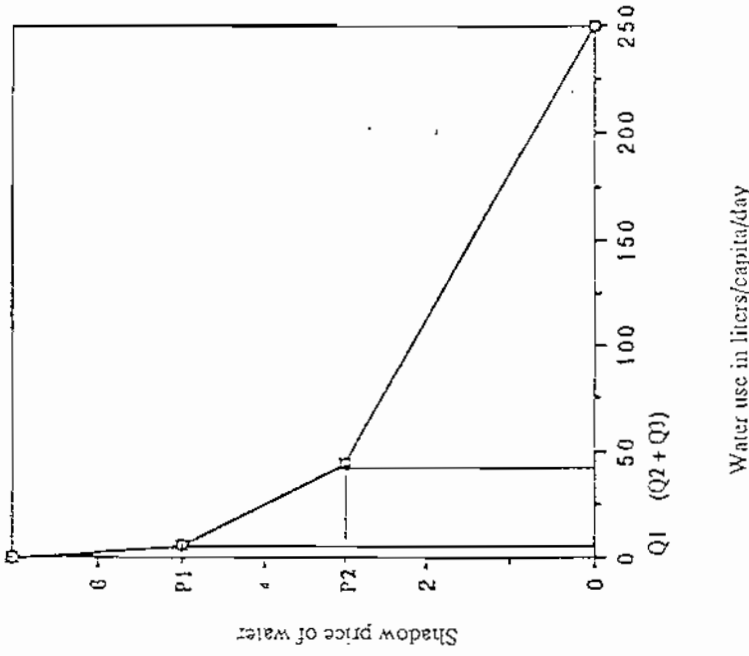
The individual's total willingness to pay for a specified amount of water is measured by the area under the demand curve for the indicated quantity. For example, suppose the individual currently uses a quantity of water Q_1 and pays (incurs) a shadow price P_1 (Figure

FIGURE 3.3
A Typical Individual's (Household's) Water Demand Curves

a. Demand Curves for Various Uses



b. Aggregate Demand Curve

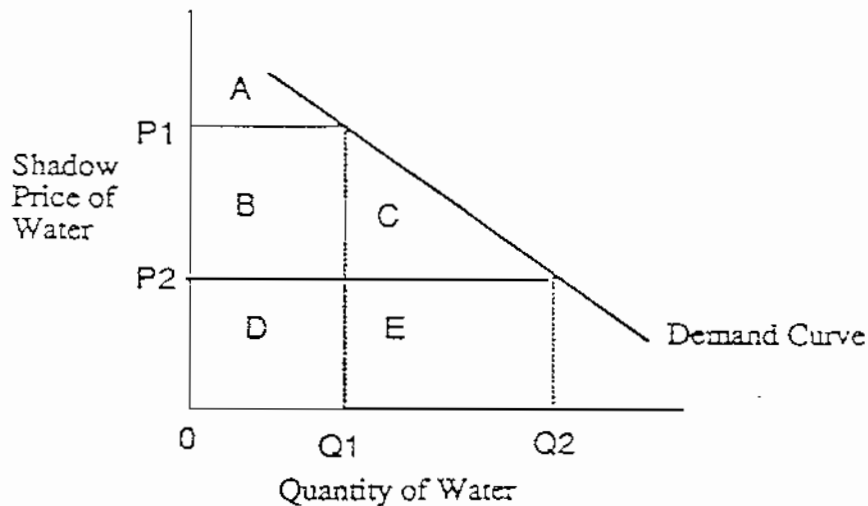


- Demand for drinking and cooking
- Demand for bathing & clothes washing
- Demand for irrigation or gardening

Source: Tottle, 1990

3.4). He is then provided water at a lower shadow price P_2 ; as a result, he uses an increased quantity Q_2 . His total willingness to pay for the original quantity Q_1 was the area $A + B + D$. He had to pay $B + D$ for Q_1 ; thus his net benefit associated with the use of Q_1 at a shadow price P_1 (that is, his consumer surplus) was area A . In fact, area A would be infinite if there were no other options available to the individual, because it would then include the benefits associated with the amount of water necessary to sustain life.

FIGURE 3.4
An Individual's (Household's) Willingness to Pay for Water



The individual's total willingness to pay for the quantity Q_2 is the area $A + B + C + D + E$ (the area under the demand curve from zero to Q_2). At price P_2 he has to pay $D + E$; his net benefit is thus $A + B + C$. Comparing the situation at price P_1 to that at price P_2 , we see that the difference in the individual's net benefits from the two cases is $A + B + C$ minus A . Thus as a result of the fall in the shadow price of water from P_1 to P_2 the individual's net benefits increase by the area $B + C$. (Note that it is not necessary to estimate the size of area A to determine the net benefits of the fall in the shadow price; it cancels out in this subtraction).

It is useful to consider the meaning of area B and of area C separately. The portion of the individual's net benefits denoted by area B is the cost savings obtained on the original quantity of water used, Q_1 . It is the amount of money and/or the value of the time, energy, and other resources saved in the purchase or collection of Q_1 . These cost savings are simply calculated as $(P_1 - P_2)$ times Q_1 .

The remaining portion of the individual's net benefits, area C , is the consumer surplus on the increased quantity of water used as a result of the fall in the shadow price of water from P_1 to P_2 . The increase in water use is $Q_2 - Q_1$; area C measures the value of $Q_2 - Q_1$ to the individual, over and above what he has to pay for this amount of water (P_2 times $Q_2 - Q_1$). If the demand curve between (P_1, Q_1) and (P_2, Q_2) were linear, area C could be calculated as $1/2 (P_2 - P_1) (Q_2 - Q_1)$. As we have seen, however, this demand curve is not likely to be linear, and, thus, that expression will provide an overestimate of the magnitude of area C .

C. The Individual's Willingness to Pay for Water: Incorporating Source Choice

This standard paradigm for conceptualizing the economic benefits of water supply improvements to an individual is incomplete in one important respect: the individual may not choose to use water from an "improved" water source. To estimate the economic benefits that an individual will obtain from access to an improved water source, it is necessary to consider carefully how much better off an individual will be after the new water system is built. This will depend on (1) the conditions under which the individual will choose to use the new source, and (2) how much water the household will use from the new source (assuming it is chosen).

Developing such an understanding of household water use behavior in a developing country is considerably more complicated than in most industrialized countries. For example, in a city in the United States there is typically just one source of water: the municipal water system (though some households may buy small amounts of bottled drinking water). The choice of water source is not a major issue there, as almost all households have multiple taps inside their homes or apartments. But in a village in a developing country there are often several water sources, each with different characteristics (such as perceived quality, reliability, distance from the household, price), and it is not at all obvious which source a particular household might select. Indeed, a household may select different water sources for different water uses (such as drinking, washing, and bathing), or even multiple sources for the same use—as might happen if the shadow price of water fluctuated due, for example, to changes in the opportunity cost of time spent collecting water. In areas where households collect and store rainwater or use intermittent streams, water use strategies may be adapted to seasonal weather patterns.

Consider a single household that moves from the countryside to a small market town in a developing country. Let us assume that this market town has three types of water sources: open wells, public taps on a limited piped distribution system, and "distributing" water vendors who obtain water from the distribution system and haul it in carts to households. The open wells are free and can be used by anyone, but it takes time and energy to lift the water from the well and to carry it home. Also, the quality of the water from the wells is not as good as that from the public taps. The public taps charge a small amount for each bucket collected, and here, too, time and energy must be expended to carry the water to the home. The water available from the vendors is likewise of good quality and also convenient, but it is very expensive compared to the other two alternatives. Which of these three sources will the household choose? And how much water will the household use?

Conceptually, the household will simultaneously decide which source(s) to select and how much water to use. Let us say that the its members need water for two different purposes: drinking and washing. Because water from each of the three sources is a different good in terms of quality and service characteristics, it is useful to think of the household as having a different demand curve for water associated with each use from each of the three sources (Figures 3.5, 3.6, and 3.7). Water from the three different sources are close but not perfect substitutes.

The vertical axis in each graph measures the real resource costs plus the money price of obtaining water from that source. For the open well, this includes the opportunity cost of time spent walking to the well, waiting in the queue if necessary, lifting water with a bucket, and walking home. For the public tap, the real resource cost includes the value of the time spent collecting water plus the price paid at the tap. Because different households

FIGURE 3.5
An Individual's (Household's) Water Demand Curves for Water from Open Wells

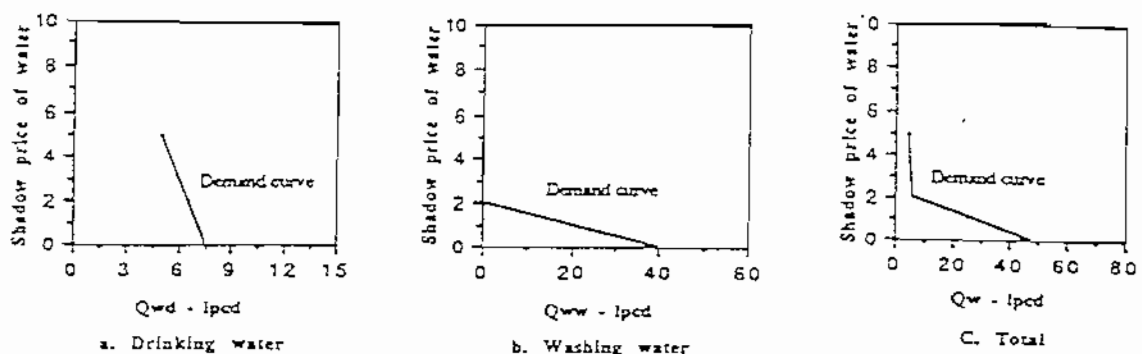


FIGURE 3.6
An Individual's (Household's) Water Demand Curves for Water from Public Taps

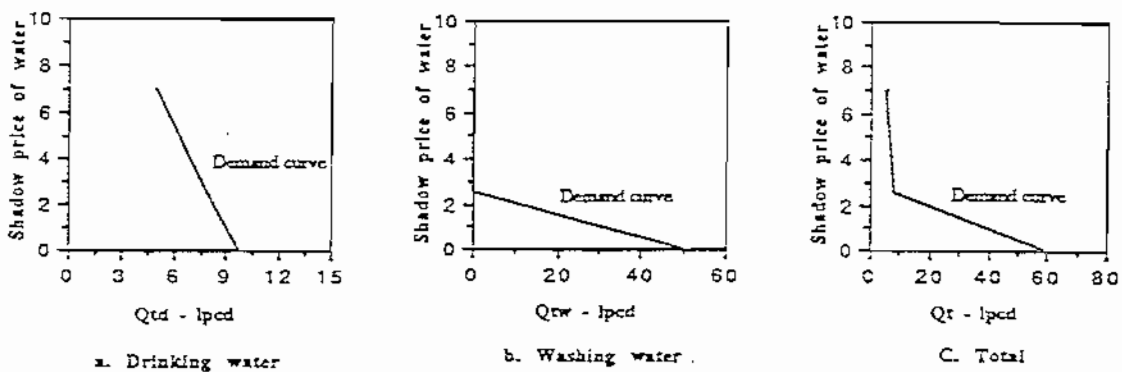
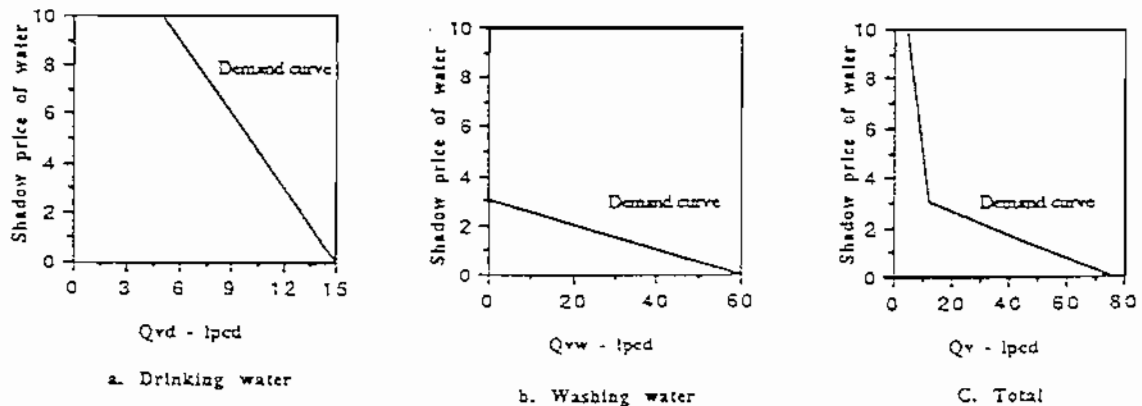


FIGURE 3.7
An Individual's (Household's) Water Demand Curves for Water from Vendors



at different distances from the open wells and public taps, and because the opportunity cost of the time spent collecting water will be different for different households, the real resource costs of using the open wells and public taps will vary across households. Let us assume that the total resource cost of obtaining water from the distributing vendors is the price paid to the vendor.

Note that our household, which is just moving into town, has some control over the real resource costs of using the three water sources. The household may select a place to live that is near a public tap or open well, or farther away. Similarly, distributing vendors may charge more to deliver water to some locations than to others, perhaps because the distance from the water source is greater or because the roads are poor. The real resource costs to the household of obtaining water from all three sources will thus be influenced by the household's residential location decision. If there is a functioning housing market in this town, housing units near a public tap or open well will likely be more expensive, other things equal, than units farther away. In this sense the real resource costs to the household of using the water sources may not be exogenous but can be determined by the household's decision on where to live in town.

Water from a single source may be used for several purposes, or for only one purpose. If our household decides to obtain water from a single source (perhaps the open wells) for both its needs—drinking (and cooking) and washing—the demand curve for its total water use can be obtained by aggregating the demand curves for those two uses for that one source (Figure 3.5 a-c). But the household might decide to collect drinking and cooking water from one source (vendors) and washing and bathing water from another (open wells). In that case its total water use would be determined by the demand curves in Figure 3.7a and 3.5b. Note that aggregating the demand curve for drinking water from distributing vendors (Figure 3.7a) and the demand curve for washing water from open wells (Figure 3.5b) is somewhat misleading, because water from two different sources is not exactly the same good, owing to differences in quality and service characteristics (even though the household may consider them to be close substitutes).

What combination of water sources will the household choose for different purposes? (Let us assume that its location in town is fixed, perhaps because its members feel bound by custom to settle near extended family who are already living in this town.³) An economic decision-making framework assumes that the household will select the source and the corresponding quantity of water used that maximizes its utility. In our graphs (Figures 3.1-3.11) marginal utility has been expressed in terms of shadow prices such that an individual's (or household's) total utility is depicted in terms of the area under the demand curve.

Let us assume that an individual's inverse demand functions for drinking and cooking water from the three sources—open wells (wd), public taps (td), and vendors (vd) are given by:

$$P_{wd} = 5 - 2 Q_{wd} \quad (3-1)$$

$$P_{td} = 7 - 1.5 Q_{td} \quad (3-2)$$

$$P_{vd} = 10 - Q_{vd} \quad (3-3)$$

³ In Chapter 4 in our discussion of the hedonic property value model, we make the opposite assumption, i.e., households are mobile and choose their housing location by comparing housing units with different attributes and neighborhood characteristics, and selecting the one that best suits their needs.

where P_{wd} , P_{td} , and P_{vd} represent the shadow prices of water from the three sources, and Q_{wd} , Q_{td} , and Q_{vd} the quantity of water used for drinking and cooking above the assumed per capita survival consumption quantity of 5 liters. (The three demand equations for drinking water are only meaningful for strictly positive values of shadow prices and water use.)

Because the first 5 liters of water consumption are required for survival, let us assume that the total utility associated with this quantity of water is equal for the three sources; it is not considered in the analysis. The intercept terms in the three demand equations depict the marginal utility (or shadow price) to the individual of a unit of water beyond that 5 liters. The individual would thus be willing to pay 5 units (measured in money terms) to get an additional liter of water from the wells; 7 units for an additional liter from the taps; and 10 for a liter from a vendor. The coefficients indicating the slopes of the demand curves show the rates at which the individual's willingness to pay (WTP) decreases for each unit of water use beyond the quantity assumed necessary for survival. These drinking and cooking water demand equations illustrate that the rate of decrease in WTP is highest for water from open wells and lowest for water from vendors.

Figures 3.8a, 3.9a, and 3.10a display these demand equations in graphical form. (The units in these equations are expressed in terms of per capita water use simply as a matter of convenience. We may assume that in everyday situations the household is the actual decision making unit, and that these individual demand curves can be easily aggregated to the level of the household.) The area below the demand curve and above the horizontal axis gives the total utility (benefits) the household perceives for selecting the water source. The consumer surplus is defined as the difference between these total benefits and the cost of the water. A utility-maximizing household will select the water source that yields the maximum consumer surplus.

The resource cost of obtaining a liter of water from the three water sources may differ. Let us assume one liter of water from open wells, public taps, and vendors costs 1, 2, and 4 units respectively. Now suppose that our household chooses open wells for drinking water. It will consume water as long as an additional unit (liter) of water consumption yields more benefit than its unit cost. The average household member will use the initial 5 liters, then consider whether to consume an additional liter of water. Because in this case (open wells) the average member's marginal benefit is 5 and her cost per liter is 1, she will choose to use the additional liter of water. Each additional liter of water use reduces an individual's marginal benefits by 2 units (note the slope of equation 3-1). After the average member consumes 2 liters (in addition to the initial 5 liters), she would decide not to collect any more water because her WTP for an additional unit of water is less than its unit cost. Along the same rationale, the average household member would use 3.33 additional liters if the household chose a public tap, and 6 additional liters if it chose a vendor.

The consumer surplus the household would derive from a decision to choose open wells for drinking water is the net benefits associated with using the additional 2 liters of water. This is represented by the triangle *A* in Figure 3.8a. The area is calculated as $4 \times \frac{1}{2} \times 2$. Similarly, the areas marked *B* and *C* in Figures 3.9a and 3.10a represent the consumer surpluses associated with choosing a public tap or a vendor as a drinking water source (8.33 and 18 units, respectively). In this example, a utility-maximizing household would select a vendor for its drinking water because this source provides the household with the largest consumer surplus.

FIGURE 3.8

An Individual's (Household's) Water Source Choice and Water Use Decisions (Open Wells)

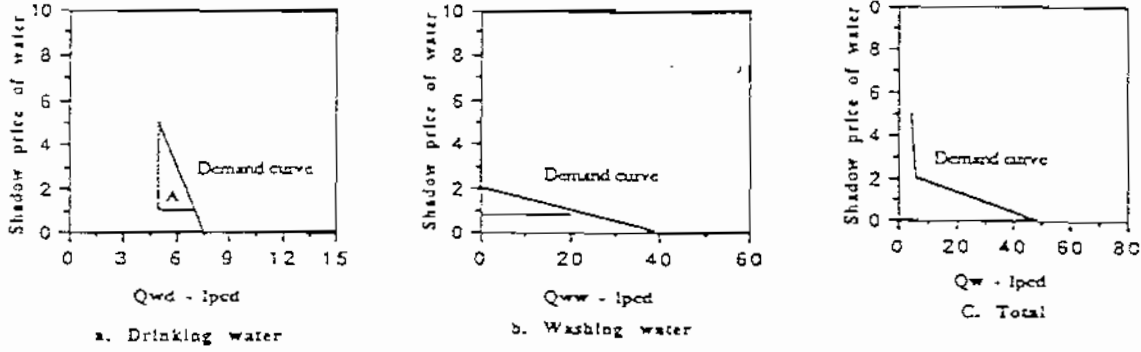


FIGURE 3.9

An Individual's (Household's) Water Source Choice and Water Use Decisions (Public Taps)

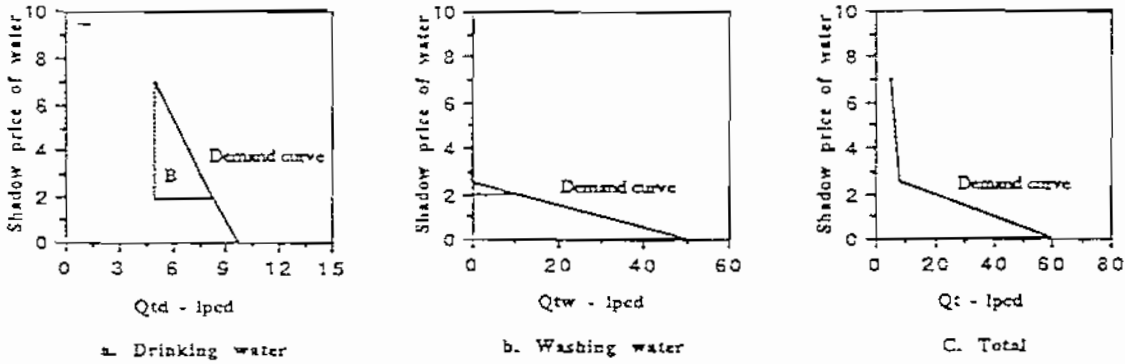


FIGURE 3.10

An Individual's (Household's) Water Source Choice and Water Use Decisions (Vendors)

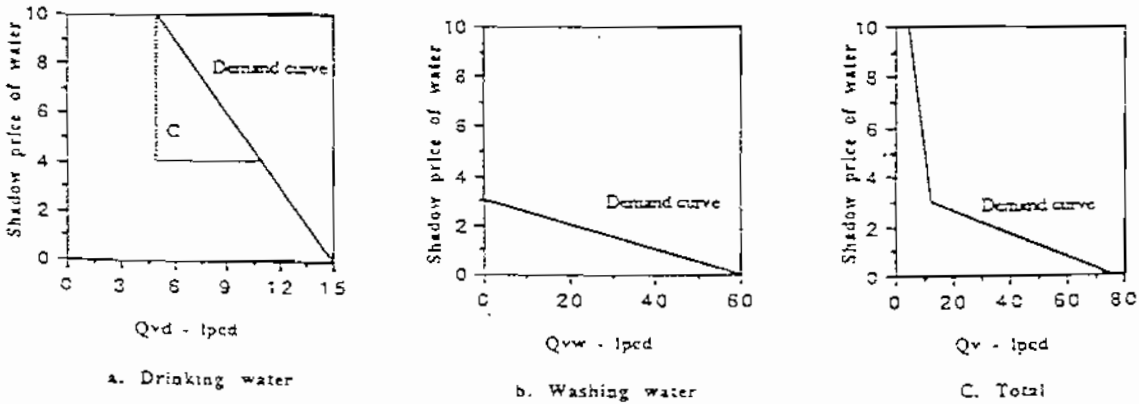
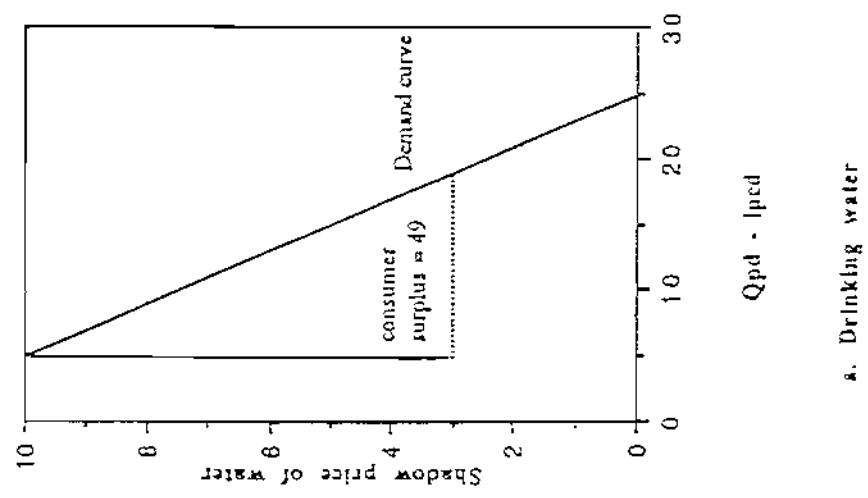
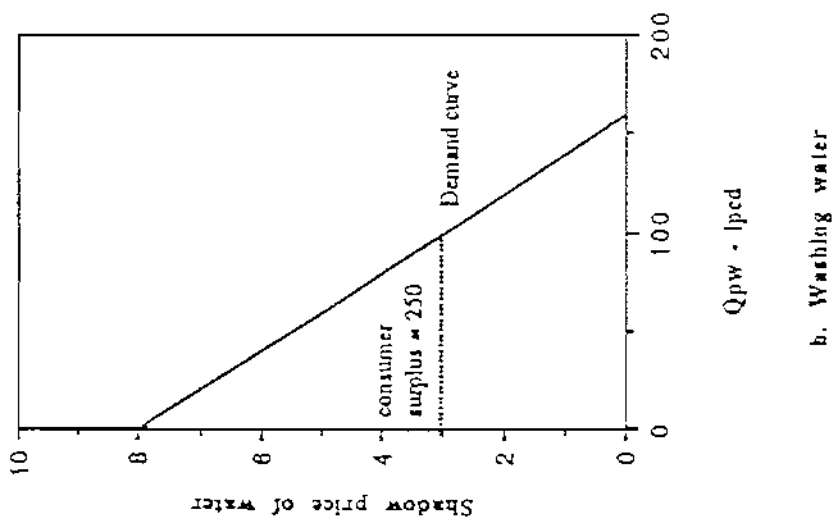


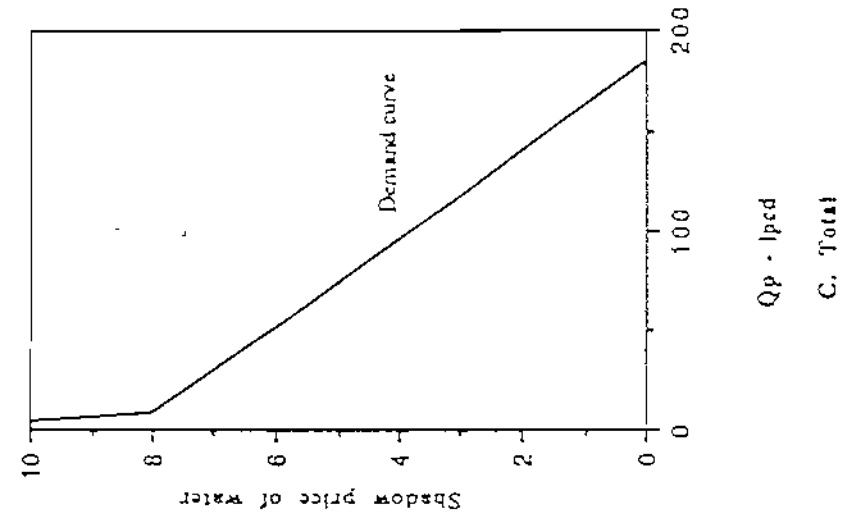
FIGURE 11
An Individual's (Household's) Consumer Surplus from the
Introduction of a Piped Water Distribution System



a. Drinking water



b. Washing water



c. Total

The household would adopt a similar procedure for selecting a water source for its other water uses (in our case, washing). For example, assume that the household's average member's demand equations for water for washing are given by:

$$P_{oww} = 2 - (1/20) Q_{oww} \quad (3-4)$$

$$P_{tw} = 2.5 - (1/20) Q_{tw} \quad (3-5)$$

$$P_{vw} = 3 - (1/20) Q_{vw} \quad (3-6)$$

where P_{oww} , P_{tw} , and P_{vw} are the shadow prices and Q_{oww} , Q_{tw} , and Q_{vw} are the quantities of water use for washing associated with open wells, public taps, and vendors, respectively.

These demand equations suggest that the household has a higher marginal WTP for vended water than for water from other sources and that the rate of decrease in its WTP for additional water use is constant for all three water sources. Note that the unit cost of water to the household will not change depending upon the water use (that is, the household pays the same for drinking water that it does for washing water from the same source). Thus, the average household member would use 10 liters of water for washing if the household selected an open well, 20 liters if it selected a public tap, and 0 liters if forced to choose a vendor. The respective consumer surpluses associated with using these sources for washing water are 10, 2.5, and 0. Because in this case an open well offers the maximum consumer surplus, the household will select an open well for its washing needs. Because the unit cost of vended water (4) is greater than the household's marginal WTP for the first unit of vended water for washing (3), the household will not buy any vended water for washing.

To summarize: the household moves to town and compares its needs and preferences for water with the money price, reliability, and quality of water from the three available sources. The household decides that its average member will consume 11 liters of vended water for drinking, and 10 liters of water from an open well for washing. If the household had selected only one source for all its water uses, then its total benefits could have been calculated from the aggregate demand equation for that source (for example, Figures 3.5c, 3.6c, or 3.7c). However, a water resource planner or project analyst would like to know not only why a household selects one water source from among the available existing sources, but also (1) whether or not the household would use a new water source if it were installed, and (2) if it did choose the new source, how much water it would then use for different purposes. This information would enable planners to estimate the potential economic benefits of the new water supply project.

For example, how would a household respond to the opportunity to have a private metered connection to a new piped water distribution system? Theoretically, the household would reevaluate its demand equations for all its water needs, considering this new option. Depending upon household preferences and any changes that might result in the unit costs of water from the traditional sources, the introduction of the piped system might or might not enable the household to increase its consumer surplus from different water uses. If the new water project does offer our (utility-maximizing) household more consumer surplus than its existing consumer surplus for a particular water use, it would select the piped water system for that water use. Assume that the water demand equations for drinking and washing from a piped system for each individual in the household are given by

$$P_{pd} = 10 - 0.5 Q_{pd} \quad (3-7)$$

$$P_{pw} = 8 - (1/20) Q_{pw} \quad (3-8)$$

where P_{pd} and P_{pw} represent the shadow prices, Q_{pd} represents the quantity of water used for drinking and cooking in addition to the 5 liters assumed to be required for survival, and Q_{pw} is the water used from the piped system for washing and bathing. Figure 3.11 illustrates these demand equations.

Assume the shadow price of piped water is 3. At this price, if the household selects a connection to the piped system, the average household member will use 19 liters for drinking and cooking, and 100 liters for washing and bathing. The consumer surpluses associated with water for drinking and cooking, and washing and bathing from the private connection to the piped water system are 49 and 250, respectively. Because the consumer surplus that each individual in the household can obtain from having a private connection and purchasing water at a price of 3 is greater than the existing consumer surplus from the traditional sources, the household selects the piped system and will satisfy all its water needs with water from the piped system.

D. Mathematical Presentation of the Discrete-Continuous Water Demand Model

We may now consider a more rigorous mathematical description of a household's water demand behavior. A discrete-continuous model is utilized to characterize how a household decides which water source to use for different purposes and how much water to use from a particular source. This discrete-continuous model has two parts: (1) a discrete choice model that describes the probability that a household will choose a particular water source, and (2) a continuous demand model that describes the quantity of water used by the household from that chosen source. In our presentation of the discrete-continuous model, we assume that (1) a household only uses one source for a particular purpose (for example, buys all drinking water from a vendor); and (2) that all households have the same set of choices (the same water sources available to choose from).

1. The Discrete Choice Model

Suppose that an individual (or household) faces a choice among J water sources, and will select only one source for a particular water use. Assume that this individual makes his water source selection(s) on the basis of the attributes of the water sources available and his socioeconomic characteristics. Each individual attaches a marginal value (or utility) to each attribute of a water source (such as price, quality, and reliability). A utility-maximizing individual is assumed to aggregate the utility obtained for all attributes of each source and then select the source that yields maximum utility (Lancaster 1965; McFadden, 1981). Thus, if q_h is the quantity of water demanded by household h for a specific use, the quantity of water demanded by household h from source j for that use, q_{jh} , will be

$$\begin{aligned} q_{jh} &= q_h && \text{if source } j \text{ is chosen} && j \in J \\ q_{jh} &= 0 && \text{otherwise.} \end{aligned} \quad (3-9)$$

From among the set of possible water sources, household h is assumed to choose alternative j if and only if:

$$U_{jh} \geq U_{ih} \quad i, j \in J \quad i \neq j, \quad (3-10)$$

ere U_{jh} and U_{ih} are "well behaved" indirect utility functions conditioned on the source choice. Let I be a dichotomous variable such that

$$\begin{aligned} I_{jh} &= 1 && \text{if } U_{jh} \geq U_{ih} && i, j \in J && i \neq j \\ I_{jh} &= 0 && \text{otherwise.} \end{aligned} \quad (3-11)$$

A planner needs to understand why a household selects water source(s) and the quantity of water it uses, but the indirect utility function is unique to each household and cannot be known to the analyst. To approximate the "true" utility function, the analyst assumes a known function based on economic theory and attempts to use it to describe households' water source selection decisions. Doing this requires data on households' water source selection decisions as well as data on attributes of the alternative sources and socioeconomic characteristics of the households involved.

It is impractical for the analyst to collect such data for each household in a community. Instead, data are conventionally collected for a representative sample of households. The behavior of some households in the sample may appear inconsistent to the analyst in terms of his assumed model of behavior. Such observed inconsistencies in water source choice behavior are assumed to result from random disturbances (Manski 1973; Ben-Akiva and Lerman 1985). The indirect utility function is thus typically assumed to have two components: a random term and a systematic (or observed) term. The addition of this random term results in "a random utility function," and the utility a household derives from a water source selection decision becomes a random variable. For example, let V be the systematic term, and e be the random term. The random utility function associated with source i is given by

$$U_{ih} = V_{ih} + e_{ih}. \quad (3-12)$$

Consequently, the source choice decision becomes

$$\begin{aligned} I_{jh} &= 1 && \text{if } V_{jh} + e_{jh} \geq V_{ih} + e_{ih} && i, j \in J && i \neq j \\ I_{jh} &= 0 && \text{otherwise.} \end{aligned} \quad (3-13)$$

This can be rewritten in probability terms as

$$\text{Prob } [I_{jh} = 1] = \text{Prob } \{ (V_{jh} + e_{jh}) \geq (V_{ih} + e_{ih}) \} \quad i, j \in J \quad i \neq j. \quad (3-14)$$

In other words, the probability that household h will choose water source j equals the probability that the utility derived from using water source j is no less than the utility derived from using any alternative source.

The distribution of U_i will depend on the distribution of the error term, and different assumptions about the distribution of the error term will lead to different mathematical specifications of the discrete choice model. A common assumption is that the error term follows a Gumbel distribution with a mean equal to zero and the scale parameter of 1, in which case equation (3-14) may be written as a multinomial logit model:

$$\text{Prob } (j) = \exp(V_j) / \sum_i \exp(V_i) \quad i, j \in J \quad i \neq j. \quad (3-15)$$

where $\text{Prob}(j)$ is the probability that the household chooses water source j (Ben-Akiva and Lerman 1985). This multinomial logit model has been widely used to model household decisions with discrete choices (Amemiya 1981).

The independent variables in the indirect utility function include two groups: (1) attributes of an alternative, which vary across sources, and (2) socioeconomic characteristics of the households, which do not vary across sources. The second group of variables are intended to explain variations in tastes among households that choose different water sources. To estimate the probability of choosing a specific alternative and the taste variation simultaneously, McFadden (1973, 1982) developed a conditional logit model. Let X be a vector of water source characteristics, and Z be a vector of household characteristics that includes income and a set of socioeconomic variables. Assuming the utility function is additive (that is, $V_{jh} = BX_{jh} + a_j Z_h$), the conditional logit model can be written as

$$P_h(j) = \exp(BX_{jh} + a_j Z_h) / \sum_i \exp(BX_{ih} + a_i Z_h) \quad i, j \in J \quad i \neq j. \quad (3-16)$$

This discrete choice model holds considerable promise as an approach to better understanding household water source decisions, but, to date, its application has been very limited (see Mu, Whittington, and Briscoe, 1990, for the one of the very few applications).

2. The Conditional Water Demand Model

The second part of the discrete-continuous model of water demand behavior is a traditional water demand model that explains the quantity of water a household uses from a particular source as a function of the household's socioeconomic characteristics (such as income and education) and the water source characteristics that vary across households using the same source (such as the shadow price of water to the household). For example, for households that choose source j , the quantity of water demanded from source j would be some function

$$q_{jh} = g_j(X'_{jh}, Z'_h) + e', \quad (3-17)$$

where X' is a vector of water source characteristics and Z' is a vector of household characteristics, both of which may be somewhat different than the vectors of independent variables X and Z used in the discrete choice model above.

Such a conditional demand function would be estimated for each water source, using data on households that chose a given source. Thus, for households that chose source i , the traditional demand function would be

$$q_{ih} = g_i(X'_{ih}, Z'_h) + e'. \quad (3-18)$$

Because a household's decisions on which water source(s) to use and the quantity of water to be used from that source are interdependent and, at least conceptually, should be made simultaneously, the error term in the discrete choice model is correlated with the error terms in the conditional water demand functions. An ordinary least squares estimation of the continuous water demand model will thus yield biased and inconsistent parameter estimates. The following procedure has been developed, however, to address this problem:

1. Calculate the inverse of the standard normal cumulative density function evaluated at P_j , the probability that a household selects source j , obtained from the discrete choice model (call this cumulative density function H_j):

$$H_j = \Phi^{-1}(P_j). \quad (3-19)$$

- Step 2. Calculate "Heckman's lambda", λ_j , (Heckman, 1979; Lee, 1981) which characterizes the analyst's uncertainty about household's water source selection behavior:

$$\lambda_j = \phi(H_j) / \varphi(H_j) \quad (3-20)$$

where ϕ and φ are the probability and cumulative density functions.

- Step 3. Estimate the continuous water demand model, including the variable λ_j as an additional explanatory variable:

$$q_{jht} = g_j(X'_{jht}, Z'_{ht}) + \lambda_{j*} e'. \quad (3-21)$$

The resulting estimates are consistent but have the wrong standard errors (Becker et. al 1987).

- Step 4. Correct the standard errors using, for example, two-stage least squares. The resulting standard errors will be consistent and efficient estimates.

This procedure seems to provide satisfactory parameter estimates for the continuous demand model (Lee and Trost 1978; Heckman 1978; Lee 1979; Maddala, 1983; Hanemann, 1984).

3. Uses of the Discrete-Continuous Model

This discrete-continuous model of household demand has been given limited application in some industrialized countries for modeling household consumption decisions in other sectors, but the full model has never been applied to the problem of modeling household water demand behavior in developing countries. There are numerous reasons for this. First, the model and the estimation procedure are still relatively new, and many applied economists are not familiar with it. Second, the field work required to collect the micro-level data necessary to estimate the discrete-continuous model is difficult, and secondary data are never available. Such primary data collection is always hard and time-consuming, but several problems make it especially so in this case. To estimate the model, one must find a situation in which there is significant variation in both the independent and dependent variables. In many places water-source decisions are not that complicated: everyone in a particular location or part of the city chooses the same water source. Even in places where some households use one source and other households use a different source, the users may in reality not have a choice. For example, some households may be connected to a water distribution system, but others that are not connected may not have the choice to connect because the water utility will not allow any more connections. In some locations water sources may disappear in the dry season, and thus limit households' source choice.

In other places there may not be significant variation across households in the shadow price of water. Variations in the shadow price of water sometimes arise because households live different distances from traditional sources and thus must spend different amounts of time and energy collecting water. In many places, however, there is little difference in the distance households walk for water. In rural areas this situation typically arises in locations where everyone must walk far from the village to collect water (and all thus walk essentially the same distance) or in places where water is plentiful and no one has to walk very far. In both cases it is impossible to use the discrete-continuous model to estimate how households will respond to a change in the shadow price of water, because there is no variation in this independent variable. (It often happens, however, that when people must walk long distances for water, water-vending enterprises will emerge to serve higher income families.)

Finally, micro-level data on the quantities of water households use for different purposes are very difficult to obtain through household interviews. Direct questions about the amounts of water used for different purposes often receive unreliable answers, because respondents are generally unable to estimate quantities of water accurately. Also, one household member may not know how much water other family members use. Direct observation of household water use is extremely time-consuming and is generally not a practical alternative. Data on water source-choice decisions are much more readily available than data on quantities of water used for different purposes. Rainwater collection and seasonal variations in water use complicate data collection efforts.

For all these reasons, collecting the data necessary to estimate the discrete-continuous model of water-demand behavior should be considered a major phase of the research process, not as something that can be done during the course of normal project appraisal efforts. The primary value of the discrete-continuous model for practitioners lies in the conceptual framework that it provides for thinking about household water demand behavior, and, in particular, its focus on the two interrelated decisions a household must make: what water source to use, and how much water to use from the source selected for a particular purpose. Future research using the discrete-continuous model may yield insights into how households make these decisions.

IV. Practical Approaches to Estimating the Economic Benefits to Households: Revealed Preference Methods

A. Introduction to Indirect Methods

Before deciding what type of improved water system to construct and promote in a community, planners would obviously like to know whether people will use such a system after it is built if different prices are charged. As financial considerations become more important to governments, user charges in the form of connection fees and monthly tariffs often must be increased. It thus becomes important for water resource planners to have detailed information on how specific groups of households will respond to different prices and connection charges.

But how can anyone really *know* beforehand whether households will connect to a *water* distribution line (or use a public tap) once it is installed? There are several ways to answer this question. One can experiment: a water line can be installed in selected areas, and one can observe how people respond to a given set of prices. Although this approach theoretically can provide relatively definitive answers, it has several practical disadvantages. First, such an experiment takes a long time to carry out; this generally makes it impractical as a means of providing information for a specific investment decision. Second, it is expensive to "experiment" with something as costly as the construction of a water supply and distribution project. Third, in such an experiment it is difficult to vary the prices and fees charged for service. An experiment may show how households will respond to a single set of prices and charges, but planners typically want to know what would happen if the price of water service were raised or lowered.

To avoid problems like these, economists have traditionally used a second approach to estimate the demand for a good or service. They try to find a situation (or many different situations) where people have been offered the opportunity to buy that good or service at different prices. With the aid of econometric techniques and economic theory, they then attempt to infer (1) how price (and other factors such as income and education) may affect households' decisions on whether to purchase the good or service (and, if a household does purchase it, how much it would buy at different prices); and (2) the maximum amount of money households would be willing to pay for the good or service.

This second approach to estimating the economic benefits of improved water supply projects to households, on the basis of actual household behavior, is the subject of this chapter. Methods based on actual behavior are termed "indirect" because economists must *infer* households' willingness to pay from observations of what people do. This second approach also has its limitations. For example, indirect methods are not feasible for estimating the demand for a *new* good or service; if no one has it yet, researchers cannot observe anyone actually using it. Even if a good or service has been available, its price may never have varied much—in which case it is impossible to determine how people would respond to a price increase merely by examining their past behavior. And even if economists find a suitable set of households in a specific city or region, for a variety of reasons those households may not respond to the introduction of a particular good or service in the same way as households in other places. An additional limitation of indirect methods is that household willingness-to-pay estimates are derived from demand models, and thus depend upon the model specification, functional forms, and theoretical assumptions used by the analyst. Thus, even though data on actual behavior are utilized, the interpretation of and inferences from these data still depend on the analyst's acumen.

There is a third approach, in which the project evaluator simply asks the respondent directly what he (or she) would do if faced with a hypothetical choice. This survey approach, commonly called the "contingent valuation method (CVM)", is the subject of our next chapter.

Many agencies prefer estimates of economic benefits that are based on what people actually do, not what they say they would do in a hypothetical situation. Thus, in the past, indirect approaches have been the most popular, not only in the water supply sector, but for project evaluation in general.

In the water sector an indirect approach to estimating households' willingness to pay for improved water service would ideally entail estimating the discrete-continuous water demand model described in Chapter III, and using it to derive measures of welfare change

for the households that chose to use the improved water source. In practice, the data necessary to estimate this model are almost never available, in large part because they are extremely difficult to collect. (This is particularly true for data on the amounts of water used in various household activities.) Other indirect techniques are thus required to develop reasonable estimates of economic benefits for project appraisal. Several such techniques are described below.

B. Estimates of Cost Savings

The simplest and easiest portion of economic benefits to measure is the cost savings to households from the improved water source. These cost savings may be in terms of the time people will save as a result of not having to fetch water, the money they will no longer have to spend buying water from vendors, the resources they will no longer have to spend to improve the quality of the water, the food they will no longer have to buy because they are using fewer calories as a result of not having to fetch water, or some combination of these. The calculation essentially entails five steps:

1. Determining the shadow price (or real resource cost) of a unit of water to households before the project is constructed (P_1);
2. Determining the shadow price of water to households after the project is constructed (P_2);
3. Estimating the quantity of water households are using before the new water system is built (Q_1);
4. Estimating the number of households in the community that will use the new system;
5. Calculating the cost savings per household by multiplying the difference in the shadow price of water before and after the project ($P_1 - P_2$) by Q_1 ; and then multiplying the number of households that will use the new system by the net benefits per household to obtain an estimate of the total cost savings.

Note that to estimate the cost savings, one does *not* need to know the quantity of water that households will use after the new water system is constructed (Q_2).

1. Cost Savings Based on Water Not Purchased from Vendors

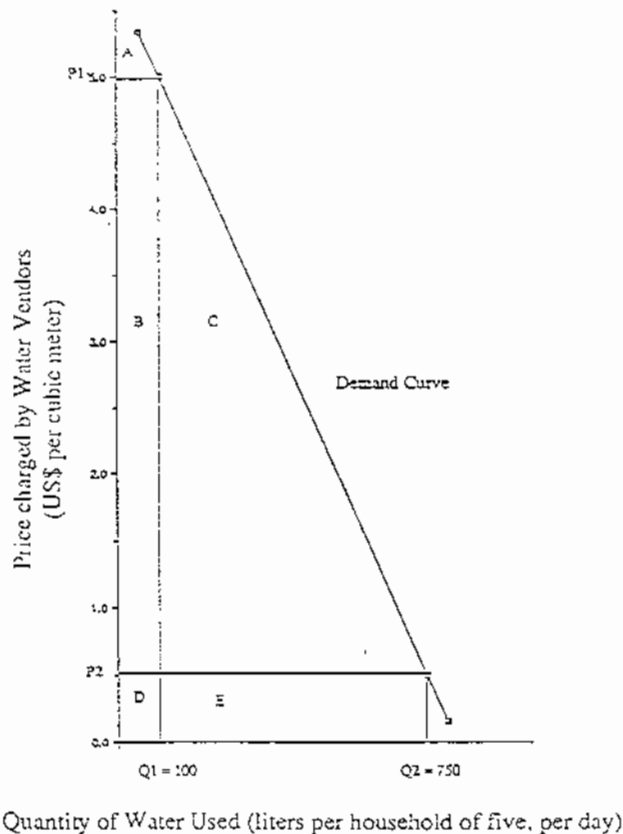
Let us now consider how the cost savings can be calculated for a water supply project constructed in a community where households are currently buying water from distributing vendors for all their water needs.

Suppose a household with five persons is currently buying 100 liters of water per day (20 liters per capita) from distributing water vendors at a price of US\$5 per cubic meter (a daily household expenditure of US\$0.50). This hypothetical situation is illustrated in Figure 4.1, in which the household initially buys Q_1 at a price P_1 . This expenditure is represented by the sum of the areas $B + D$. Let us assume the household incurs no other costs in using vended water. (In some situations, for example, where large tanks are required for storage of water purchased from tanker truck vendors, the costs of storage could be significant; but in most cases storage costs are quite small per unit of water.)

Now suppose that a new water supply system is constructed in this community and that households have the option of connecting to the system and having a private metered connection. Assume that the price of water from a private connection is US\$0.50 per cubic meter (P_2 in Figure 4.1). If the household connects, its daily expenditure for Q_1 (100 liters of water) will be US\$0.05, representing a cost savings associated with the initial quantity of water used of US\$0.45 per day (area B in Figure 4.1).

This estimate of the cost savings is only a portion of the total benefits to the household: it does not include the consumer surplus the household receives on the quantity of water it may use in addition to Q_1 (area C in Figure 4.1). Nevertheless, this estimate of the cost savings alone is still nine times greater than the revenues the water utility will receive from this household for the sale of Q_1 .

FIGURE 4.1
A Household's Willingness to Pay for Water:
Estimates of Daily Cost Savings and Consumer Surplus



The data requirements for the calculation of the cost savings are quite modest. The only information needed is (1) the average quantity of water a household purchases from vendors, (2) the price vendors charge for water, and (3) the price of water charged by the water utility. All these data are relatively easily obtained from a household survey and other simple inquiries. Note, in particular, that an estimate of the entire demand curve for water is not necessary, nor do we need to know how much water the household would purchase from the piped distribution system once it had obtained a connection (Q_2 in Figure 4.1).

To develop an aggregate estimate of the cost savings for an entire community, the only additional information necessary is the number of households currently using water vendors who would connect to the piped system. If the prospective cost savings are large, one would assume that most households would choose to connect. Yet that may not be the case: there are numerous reasons why some people may prefer to continue to use vendors (see Whittington, Okorafor, Okore, and McPhail, 1990). For instance, (1) they may want to avoid making a firm commitment to pay the water utility every month; (2) they may not want to become involved with a government agency; (3) they may be renters who do not want to make the investment required for a connection in property they do not own. It is thus important to ask individual households whether or not they would choose to have a private connection. Alternatively, the project analyst can try to find a comparable community that has already installed a water system and see what percentage of the households there decided to connect. One must then assume that households in the community that is being analyzed will behave in a similar manner.

If water vending is widespread in a community, the cost savings can be very large indeed. For example, suppose that in a community of 5,000 people (with an average of five persons per household), 50 percent of the households were obtaining all their water from vendors. In that case 500 households would receive the full estimated cost savings. If the cost savings to a single household is US\$0.45 per day, the annual savings per household is US\$164, and the annual total cost savings for the 500 households is US\$82,125! It is important to emphasize again that this is only a hypothetical example and that this estimate of US\$82,125 is only a portion of the economic benefits. It does not include either (1) the consumer surplus that connected households obtain on water they use in addition to Q_1 or (2) the economic benefits to the 50 percent of the households in the community not connected to the new water system (such as the possibility of purchasing water from households that now have private connections). Nevertheless, calculations of annual cost savings can provide compelling evidence of the economic feasibility of many proposed water projects.

2. Cost Savings Based on the Value of Time Saved by Not Having to Fetch Water

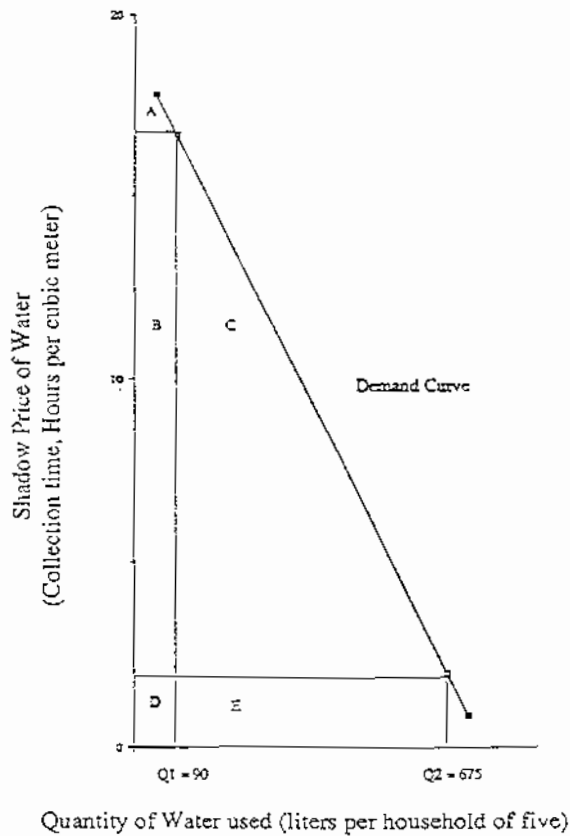
In many communities in developing countries water vending does not exist; households obtain their water by walking to traditional sources and carrying water home. In such situations estimates of cost savings obviously cannot be based on expenditures no longer made to vendors, as described above. If a water supply system will reduce the amount of time households spend fetching water, an estimate of the cost savings can be obtained by multiplying the amount of time saved by an estimate of the money value of that time.

Consider a household of five persons that uses 90 liters of water per day. Assume that women in the household spend 1.5 hours per day collecting this 90 liters of water, perhaps by making five round-trips to a well, each taking 18 minutes. Thus, overall, each liter of water takes one minute to collect. In this case we may assign a "time-price" of one minute per liter, or 16.7 hours per cubic meter. In Figure 4.2 the vertical axis expresses time-price rather than US\$ price (as in Figure 4.1). The downward-sloping demand curve for water indicates that as collection time per cubic meter decreases, the quantity of water collected will increase.

If the project analyst could estimate the monetary value that a household assigns to the time spent fetching water, it would be possible to transform the demand curve in Figure 4.2

into a typical demand curve in which price is expressed in monetary units. For example, suppose the hourly wage for unskilled labor in the community is US\$0.25, and that the household values the time it spends fetching water at one-half this wage rate. A time-price of 16.7 hours per cubic meter of water would then be equivalent to US\$2.09 per cubic meter (16.7 hours at US\$0.125 per hour) or US\$0.19 for the household's 90 liters per day.

FIGURE 4.2
A Household's Willingness to Pay for Water:
Estimates of Daily Time Savings



With this monetary estimate of the price of water, it becomes possible to calculate the magnitude of the cost savings from a piped water supply system. Suppose the household connects to the new system and can (as in our prior example) purchase water for US\$0.50 per cubic meter. The household would spend US\$0.045 per day purchasing its customary 90 liters. The cost savings would thus amount to about US\$0.14 per day from the US\$0.19 it had "spent" before. Over the course of a year these savings would amount to about US\$53.

This estimate of the economic benefits from time savings requires only the following data: (1) the amount of time the household spends per day fetching water, (2) the amount of water collected, and (3) the monetary value of time spent fetching water. The first two items can be roughly estimated from responses to questions in a household survey, but respondents may not be able to estimate the time spent collecting water very accurately. Nor is it easy to estimate the quantity of water collected if water is carried in containers of many

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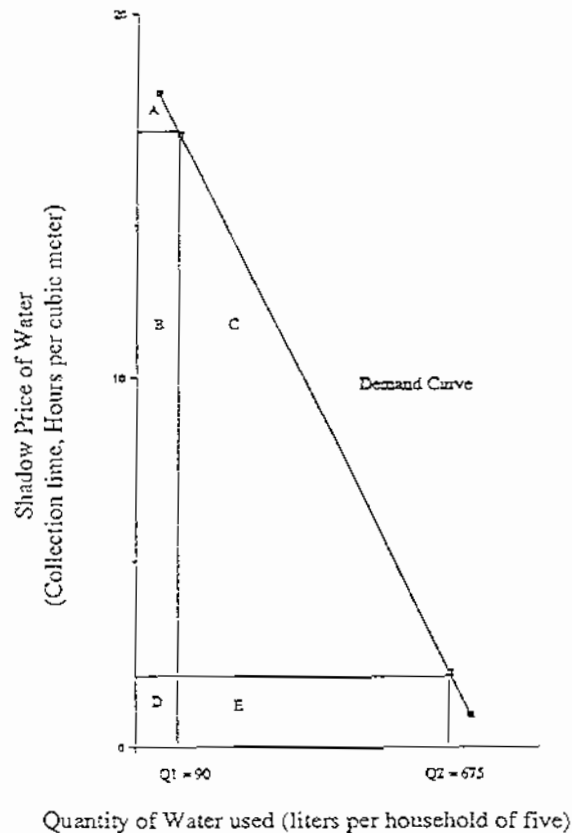
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different sizes. The best approach is usually to observe households collecting water at the source, to get an estimate of queue times and the quantities of water collected, and to walk with women from several households to their water source and back, to get an estimate of the time spent per trip.

It is generally not feasible to undertake a rigorous analytical study of the value households assign to the time they spend fetching water. The only practical approach may be to *assume* a value for the time savings and then carry out a sensitivity analysis to see how that assumption affects the estimates of economic benefits. For example, in the past the Inter-American Development Bank has assumed in its procedures for appraising water projects that the value of time spent collecting water should be valued at one-half the wage rate for unskilled labor in the project area (just as we did above). There has, however, been little empirical support for this assumption. Recent evidence suggests that the value of time spent fetching water can be surprisingly high (Whittington, Mu, and Roche 1990). A study of a small market town in Kenya found that the value households assign to the time spent fetching water was approximately equal to the full market wage rate for unskilled labor. (In such a situation one would expect water vending to flourish, as was indeed the case in that town.)

In many agricultural communities the value of time spent fetching water may vary significantly depending on the time of the year. In the planting and harvesting seasons, the value of time spent fetching water may approach the market wage rate; at other times of the year there may be excess labor in the economy, and the value of time spent hauling water may be very low. In such cases the value assigned to time savings should reflect local seasonal conditions.

To estimate the aggregate benefits from time savings to an entire community, it is again necessary to know the number of households who will decide to connect to the new distribution system. For example, again consider a community of 5,000 people with an average of 5 persons per household, and assume that 75 percent of these 1,000 households decide to connect to the new water system. The total annual value of the time savings would be approximately US\$40,000 (750 households times US\$53 per household). If the value of time spent carrying water was, instead, equal to the market wage rate for unskilled labor, the total value of the time savings would be almost US\$80,000 per year.

Such estimates would reflect only a portion of the economic benefits. In fact, they may be useful in establishing a lower bound on the economic benefits. Such a lower-bound estimate may be quite large: in this example it exceeds four times the revenues collected by the water utility on sales of the first 90 liters per day to each connected household.

3. Cost Savings Based on Not Having to Boil Water

In addition to money and time savings, households may experience benefits from no longer having to improve the quality of water. In some countries (such as China and in parts of Indonesia) households commonly boil their drinking water. In other areas alum is sometimes added to drinking water in order to improve its quality. The introduction of an improved water system will, to some extent, result in savings of time, fuel spent boiling water, and additives such as alum. Estimating such cost savings for boiling water or adding alum works much the same as for vending and time savings. The analyst must estimate the real resource costs that the household incurs by obtaining its current water supply on a per unit basis.

For example, a calculation for boiling water might require that the analyst estimate both the time required to boil water and the amount of firewood used to boil a liter of water, and assign a value to each. The value of the wood could be based on the value of time household members spend collecting it, or on its market value—or even the market value of the wood plus the value of the time spent hauling it home from the market.

Estimates of these various types of cost savings need not be mutually exclusive. It is certainly possible that the real resource cost of water to the household will include both the time spent fetching water and the value of the time and resources spent boiling it. Estimates of the total cost savings should be based on the real resource cost per unit of water before the project.

C. Estimates of the Consumer Surplus on the Increased Quantity of Water Used

The second portion of the benefits of an improved water supply is the consumer surplus on the increased quantity of water used as a result of the fall in the shadow price of water. If the relevant demand function(s) for water were known, it would be a straightforward exercise to calculate this consumer surplus associated with the increased supply of water ($Q_2 - Q_1$). Problems arise, however, because of the difficulty of estimating the appropriate demand function(s) for different water sources and uses. These demand functions cannot be estimated because the kind of detailed micro-level data required are simply not available. Even extensive household surveys have great difficulty obtaining reliable data on water use from different sources for different purposes.

An alternative would be to obtain demand functions from the literature, and to simply assume that they are applicable to households in the project area under study. This approach is of limited usefulness, however, because there are very few such water demand studies in the literature (for exceptions, see Meroz 1968, Katzman 1977, Hubbell 1977, Mu, Whittington, and Briscoe 1990). The project analyst is unlikely to find an example in the literature that approximates conditions at hand.

We recommend a third approach: one can assume a functional form for the water demand relationship (e.g., linear or log-linear), and estimate the quantity of water that is likely to be consumed (Q_2) at the price to be charged (P_2). Given the two points (P_1, Q_1) and (P_2, Q_2), and the assumption of a functional form, the demand function can be defined over the relevant range of values of Q_2 , and the consumer surplus can be determined. The first step is to calculate the cost savings $(P_1 - P_2) \times Q_1$. The second step is to multiply the cost savings by a "c-factor," which is defined as the ratio of the consumer surplus to the cost savings. The product of this multiplication of the cost savings and the c-factor is thus an estimate of the magnitude of the consumer surplus.

These c-factors will change for different values of P_1, Q_1, P_2, Q_2 , and the functional form of the water demand relationship. However, for a specific project area the values for P_1, Q_1 , and P_2 will be known or can be determined during the appraisal process. The two remaining unknowns are the functional form and Q_2 . Appendix 1 presents analytical expressions of the c-factors for the three functional forms so that c-factors can be easily estimated. Using these equations the analyst may simply choose the values of P_1, Q_1 , and P_2 that most closely correspond to the situation in the project area under study, and easily estimate the size of the consumer surplus relative to the cost savings, assuming a value of Q_2 and a functional form.

The advantage of this procedure is that it conveniently relates the magnitude of the consumer surplus to the cost savings. For example, consider again our first example above (chapter IV, p. 32), where $P_1 = \text{US\$}5.00$ per cubic meter; $P_2 = \text{US\$}0.50$ per cubic meter; and $Q_1 = 20$ liters per capita per day. If we assume that households will consume approximately 100 liters per capita per day after the piped water system is installed (and $P_2 = \text{US\$}0.50$), then for a log-linear demand function, the consumer surplus would be about 0.8 times as large as the cost savings (i.e., the c-factor = 0.8). Since the cost savings is $\text{US\$}0.45$ per day, the consumer surplus is approximately $\text{US\$}0.36$ per day.

This procedure enables the project analyst easily to separate the estimate of cost savings from the estimate of consumer surplus. This is useful because in many cases cost savings will appear to be more reliable and less speculative estimates of benefits than estimates of consumer surplus. Decision makers will often prefer to keep these two components of project benefits separate. If the project can be justified on the basis of cost savings alone, estimates of consumer surplus can only strengthen the economic arguments for the project. If the cost savings alone are not greater than the project costs, estimates of consumer surplus will be required. In that case it may be useful to know that the cost savings are, for example, equal to 80 percent of project costs, and that the consumer surplus appears to be at least equal in size to the cost savings. Thus, although the estimate of consumer surplus may be somewhat speculative, in this example it appears to be almost as large as the cost savings benefits.

The choice of the functional form of the demand curve can affect the c-factor significantly. The assumption of a linear functional form implies that the absolute value of the price elasticity of demand is higher (i.e., demand is more *elastic*) at low levels of water consumption. In other words, if the price of water is high and water use is low, a given percentage increase in price results in a greater percentage decrease in the quantity of water demanded than at a lower price level. This situation would be true for some consumer goods and services. However, it seems unlikely to accurately characterize water use behavior when the price of water (or its real resource cost) is high and household water use is low, as is the case in many developing countries. For example, when household water use drops to 10-15 liters per capita per day, there is very little more substitution possible between water and other goods that a household can undertake. The household must maintain minimal levels of water use to survive, and any water price increases simply cannot have much more effect on water use (although such price increases can dramatically lower real household income).

The assumption of a log-linear specification implies that the price elasticity of demand is constant at all levels of water use. This also seems unrealistic when an analyst wishes to model the effects of price changes at low levels of household water use. Thus, at the low levels of water use and high real prices existing in many places in developing countries, the assumption of a linear or log-linear water demand function is inappropriate. Both are likely to overestimate the magnitude of the consumer surplus associated with the increased quantity of water used when households are using small quantities of water before the installation of the improved water supply. However, the log-linear form is likely to provide a better estimate than the linear form (or the exponential form). Also, the log-linear form is likely to provide a reasonable approximation of the actual demand relationship when households are already using considerable quantities of water (i.e., when households already have a connection to an existing piped distribution system and the new project is designed to increase the reliability and quantity of water available). It is thus recommended that the

log-linear form be used to calculate the c-factor unless the analyst has good reason to believe that the linear or exponential form is more appropriate for a particular project site.

Still, the analyst should bear in mind that all three of these functional forms are at best crude representations of household water demand behavior. The fundamental underlying problem with the attempt to find a functional form for the traditional water demand model is that the household's choice set is considerably more complex than a continuous single-equation demand model implies. As discussed in Chapter III, as the price of water changes, the individual household may change *both* water sources and water uses. The estimates of consumer surplus obtained from this c-factor procedure should thus be considered crude, speculative approximations of the economic benefits associated with the increased water consumption.

D. The Hedonic Property Value Approach

1. Introduction

The basic idea underlying the "hedonic property value" approach to estimating household demand for improved water services is that when making a decision on what house to buy or what apartment to rent, households will consider the value (to them) of any available water services associated with the housing unit and that this information on the value of water services can be recovered from a careful analysis of transactions in the housing market. These transactions could either involve sales of property or agreements to rent housing units. Households that value improved water services should be willing to pay more for housing units with better water facilities. Of course, many factors other than water services influence the sales price or rent of a housing unit. By using the hedonic property value approach, the economist attempts to control for these other factors and to obtain an estimate of the incremental amount that households would be willing to pay to have the improved water service, assuming that other factors remain constant.

2. Theoretical Framework

A family's housing unit is assumed to be described by a list of attributes, such as square footage, type of construction, lot size, neighborhood characteristics—one of which is its access to improved water services. Let Z be a vector of attributes of the housing unit ($z_0, z_1, z_2, \dots, z_{\text{water}}, \dots, z_m$), where z_j is one of the m attributes of the housing unit and z_{water} describes the access or availability of improved water services to the housing unit. A household is assumed to maximize the utility it derives from the consumption of these attributes and the consumption of all other goods and services (denoted by a composite market good Q) subject to its budget constraint:

$$\text{Maximize } U(Q, z_0, z_1, z_2, \dots, z_{\text{water}}, \dots, z_m) \quad (4-1)$$

$$\text{subject to } pQ + r(z_0, z_1, z_2, \dots, z_{\text{water}}, \dots, z_m) = Y \quad (4-2)$$

where

p = price of the composite market good;

$r(Z)$ is the hedonic price function that relates the market price (or rental value) of the housing unit to its attributes; and

Y = household income.

The household is assumed to spend all its income on the purchase of its housing and all other goods and services, trading off consumption of housing and all other goods and services in order to attain the maximum utility possible. The first order conditions for a solution of this utility maximization problem require that ...

$$\partial U / \partial z_j / \partial U / \partial Q = MRS_{z_j, Q} = \partial r / \partial z_j \quad \text{for } j = 1, \dots, m. \quad (4-3)$$

This implies that the household's marginal rate of substitution of an attribute z_j and the composite good Q can be characterized by how much more the household is willing to pay in rent (or increased purchase price of the property) in order to obtain more of the given attribute. In particular, the household's marginal willingness to pay for the housing attribute of improved water service, z_{water} , must be equal to the implicit price of z_{water} , given by the partial derivative of the hedonic price function with respect to z_{water} , i.e., $\partial r / \partial z_{\text{water}}$ (Palmquist 1991).

The hedonic property value approach to estimating households' willingness to pay for improved water services has two parts. The first is to empirically estimate the hedonic price function $r(z_0, z_1, z_2, \dots, z_{\text{water}}, \dots, z_m)$. The second is to use the implicit price of z_{water} , $\partial r / \partial z_{\text{water}}$, to estimate an inverse demand curve for this housing attribute, and use it to estimate the economic benefits of improved water services to households (Rosen 1974; Follain and Jimenez 1985).

Different functional forms have been used in the literature for estimating the hedonic price equation. In order to carry out the second step of the approach, a twice-differentiable functional form is required for the hedonic price equation in the first step (Palmquist 1991; Cropper et al. 1988). One option is the log-linear (or log-log) function .

The estimation of the hedonic price function requires data on property values of houses or monthly rental prices for apartment units, as well as data on the factors that determine these housing prices. A multiple regression analysis is then conducted to relate these housing prices to the independent variables that are hypothesized to determine the price of a housing unit. Two types of independent variables are required for this analysis: (1) variables that describe the characteristics of the housing unit itself (number of rooms, type of water service, quality of housing construction, size of lot, distance from a paved road, central business district, market, church, etc.); and (2) variables that describe the neighborhood in which the housing unit is located (crime rate, environmental quality, quality of schools).

Both categorical and continuous independent variables can be used to describe the access or availability of water service to a housing unit. If some housing units in the study area have a private connection to an existing piped distribution system, and other housing units do not, then the existence of a private connection can be represented in the hedonic price equation by a dummy variable (i.e., whether or not the housing unit has a connection). The coefficient on this dummy variable in the estimated equation will indicate the implicit value of a private connection. It can be interpreted as the premium that a buyer (or renter) would have to pay to have a housing unit with a private connection, other things being equal. Some households with connections would, of course, have been willing to pay more than the estimated implicit price for a private connection. For them, the implicit (market) price is an underestimate of the economic benefits they would derive from having a connection. For households without connections the implicit price obtained from the hedonic price equation would presumably be an overestimate of the economic benefits of a

connection because they did not choose to pay this premium to obtain a housing unit with improved water service. The more homogeneous households' preferences for improved water services, the better the estimated coefficient from the hedonic price equation will approximate households' willingness to pay for a private connection.

Access to a water source outside the home may also be reflected in the price of a housing unit. If an improved system of public taps or handpumps is installed in a community, housing units near the public taps (or handpumps) might command a higher price than units farther away. In this case the hedonic price equation would include a continuous variable denoting the distance of the housing unit from the public tap. The estimated coefficient on such a continuous variable in the hedonic price equation would reflect households' marginal willingness to pay to be closer (e.g., an additional meter) to the public tap. Again, some households in the sample would probably be willing to pay more than this; others less.

The hedonic property value model assumes that (1) households can freely investigate available housing in different locations to find a unit with the best attributes, considering the price that must be paid, and (2) there is an active, competitive housing market. Hedonic price equations are often quite successful in explaining a large proportion of the variation in housing prices or rents if variables on both housing characteristics and neighborhood characteristics are available, and if a reasonably well-functioning housing market is in operation.

In a large, competitive housing market, the hedonic price function, $r(Z)$, is the result of actions by both consumers and suppliers of housing (i.e., it is *neither* a supply nor a demand curve for housing). The second step in the hedonic property value approach is to derive an estimate of the inverse demand function for a particular housing attribute, in this case the availability of the improved water source. To do this, the analyst calculates the partial derivative of the hedonic price equation with respect to the housing attribute, $\partial r/\partial z_j$, for the sample households, and uses these values as the dependent variable to estimate the inverse demand function for a housing attribute j :

$$\partial r/\partial z_j = f(z_j, Y, S) \quad (4-4)$$

where S is a vector of household socioeconomic characteristics.

This inverse demand function describes how the marginal value of the attribute changes with changes in the quantity of the attribute provided and the socioeconomic characteristics of the sample households.

This inverse demand function for the housing attribute can be used to calculate the economic benefits to households of changing the quantity of the specific housing attribute. For example, suppose the housing attribute was "distance to a public tap", and additional public taps were added to an existing system of public taps, reducing the distance of a certain proportion of housing units in the community from 200 meters to 50 meters. The integral of this inverse demand function from 50 to 200 meters would provide an estimate of the economic benefits to a household (with specified income and socioeconomic characteristics) of this change.

3. A Numerical Example

This example illustrates the procedure for deriving the inverse demand function for a continuous housing attribute, in this case accessibility of a housing unit to a public tap. We

The welfare change that a household (with a given income) obtains from reducing the distance of its housing unit to the public tap can be calculated by integrating this inverse demand function for accessibility over the relevant range of distance to the public tap. For example, in Figure 4.3, the economic benefit to a household with a monthly income of US\$ 80 of reducing the distance of its housing unit to the public tap from 500 meters to 300 meters is given by the area *A* (which is approximately US\$20 per month).

4. A Practical Approach for Discrete Housing Attributes

The second step of the hedonic property value model is most relevant when the analyst is concerned with measuring the economic benefits associated with changes in a continuous variable describing a housing attribute. When the improved water service can be characterized as a categorical (dummy) variable (i.e., a household either has a connection to a piped system or it does not), there is a simple, practical approach for approximating the economic benefits different groups of households derive from a private connection. First, the analyst separates the sample households into distinct groups or subsamples that he or she thinks will have different willingness to pay for a private water connection (e.g., low-income, middle-income, and high-income households). Next, the analyst estimates the hedonic price function for each subsample separately:

$$\text{rent}_{\text{low-income holds}} = \beta + \alpha_0 z_0 + \alpha_1 z_1 + \alpha_2 z_2 + \dots + \alpha_{\text{water}} z_{\text{water}} + \dots + \alpha_m z_m + \varepsilon \quad (4-8)$$

$$\text{rent}_{\text{middle-income holds}} = \beta' + \alpha_0' z_0 + \alpha_1' z_1 + \alpha_2' z_2 + \dots + \alpha'_{\text{water}} z_{\text{water}} + \dots + \alpha_m' z_m + \varepsilon \quad (4-9)$$

$$\text{rent}_{\text{high-income holds}} = \beta'' + \alpha_0'' z_0 + \alpha_1'' z_1 + \alpha_2'' z_2 + \dots + \alpha''_{\text{water}} z_{\text{water}} + \dots + \alpha_m'' z_m + \varepsilon \quad (4-10)$$

The estimated coefficients associated with the housing attribute of a private connection from these separate hedonic price equations— α , α' , and α'' —indicate the marginal willingness to pay of the three income classes for this improved water service. These separate estimates of marginal willingness to pay can then be taken as estimates of the mean economic benefits of a private water connection to each of the three groups. If the analyst can then estimate the number of households in each income group that will be provided with improved service, he or she can approximate the total economic benefits of the project. This is done by multiplying the number of households in an income class (that are to be provided with service) by the marginal value of the service for that income class estimated from the hedonic price equation, and then summing these estimates for all income classes.

5. Applicability of the Hedonic Property Value Approach

It has been commonly believed that hedonic property value models are of limited usefulness for estimating the demand for improved water services in developing countries. Housing markets are often distorted (or even nonexistent) in some developing countries. Particularly in rural areas, the assumption of a well-functioning housing market is often farfetched. In urban areas rents are often controlled, so that households cannot reveal their preferences for improved water services in rent premiums for water services. Even in places where housing markets function reasonably efficiently, secondary data for estimating the hedonic property value model on housing prices and characteristics of housing units are

ely available.⁴ There are very few studies that have applied the hedonic property value model to the problem of estimating household demand for improved water services in developing countries (Jimenez 1982; Follain and Jimenez 1985; Quigley 1980; and North and Griffin, 1993).

There are several reasons why these conventional doubts should be reconsidered. First, as more and more economies in developing countries move toward increased reliance on market organizations and economic liberalization, housing markets are becoming increasingly deregulated. Thus, there are more and more places where one can expect to obtain meaningful information on the value of water services from observations of the housing market. Second, urban areas are growing rapidly throughout the developing world, and donor agencies and national governments have increasingly focused on water problems in urban and periurban areas (including market towns). One would expect that well-functioning housing markets are likely to develop first in urban areas (if they do not already exist). Hedonic property value models are likely to be most applicable in areas where information on household demand for improved services is most needed. Third, the hedonic property value model can be implemented with data obtained from relatively simple surveys. In the past most analysts who have used the hedonic property value approach have tried to work with secondary data on housing prices and characteristics; such data are often unavailable or of questionable quality in developing countries. Yet because they are used to working with secondary data, analysts rarely think about the possibility of collecting primary data when they consider using the hedonic property value approach.

In fact, it is fairly easy to carry out a household survey to collect the data necessary to estimate the hedonic property value model. Respondents will readily know the answers to questions about housing and neighborhood characteristics, and such questions are not particularly sensitive or difficult to ask. Data collected from tenants on current rents will be of higher quality than data from homeowners on the likely (or projected) sales price of their housing units. However, people generally know the approximate market value of their own house, and the variance of data on housing prices can be partially compensated by increasing the sample size.

Household surveys can also be used to ask respondents directly about the effect of water services (or lack of them) on the value of their housing units. People can often provide very reasonable answers to a question such as "How much would this apartment rent for if it had a private water connection?" (or "if it did not have a private water connection?"). Although such questions are hypothetical, they are not abstract or difficult to answer if there is a well-functioning housing market. (The enumerator should, however, be careful to clearly specify the terms under which the household would have to pay for the water if the house had a private connection.)

Homeowners can similarly be asked directly about the effect of improved water services on the sales prices of housing properties, but their answers may sometimes be more difficult to interpret. This is particularly true in periurban and squatter areas, where households with insecure land title may be willing to pay for a connection to a piped water distribution system partly in order to increase their legal claim to their property. In this case the value they will attach to property with a private water connection may reflect not only

⁴ By "secondary data" we mean data that are available to the analyst or can be obtained without "primary" data collection efforts. Census data or other published data would be an example of secondary data. Carrying out household surveys would be a "primary" data collection technique.

the value of the improved water services per se but also the increased tenure security that results from the provision of service.

It is important to note two characteristics of the measures of economic benefits obtained from the hedonic property value model. First, a household may pay a rent premium (or higher purchase price) to live in a housing unit with a private connection but it must *still* pay the month tariff.⁵ The marginal willingness-to-pay estimates from the hedonic approach thus measure the benefits to the household *in addition to* the tariff. The total monthly economic benefits to a household would be the estimate of willingness to pay from the hedonic approach *plus* its expenditures to the water utility. The analyst must thus be careful when comparing estimates of economic benefits from hedonic property value and contingent valuation approaches.

Second, the hedonic property value approach can be used to obtain estimates of the economic benefits of a private connection, but it cannot help analysts understand how changes in the price of water will affect the quantity of water a household uses. In other words, it does not yield a demand function for water. It is thus of limited usefulness in the design of tariffs. Nevertheless, in some situations hedonic property value models may offer a promising alternative to estimating households' willingness to pay for improved water services.

E. Concluding Remarks

Taken together, Chapters III and IV present a dilemma for project evaluators working in the water sector. In Chapter III we argued that the standard paradigm for interpreting an individual's (or an individual household's) demand for improved water services was inadequate, because it did not address the issue of source choice. Here in Chapter IV, however, we have suggested that the micro-level, household data necessary for estimating the discrete-continuous model of household water demand are, in fact, not available (and are too difficult to collect as a routine part of project appraisal exercises). Instead of relying on the discrete-continuous model, we have recommended a simple, two-step approach to estimating the economic benefits:

1. Estimate the real resource costs to households of using the current source(s) (P_1), and use this to estimate the cost savings obtained from the introduction of the improved water system $(P_1 - P_2) \times Q_1$.
2. Estimate the consumer surplus on the increased quantity of water on the basis of an assumed demand function and educated guesses about the quantity of water that households will use from the improved source (Q_2).

In order to use this two-step procedure to develop a community-level estimate of economic benefits, the analyst must still address the question of how many households will use the improved water source. One cannot assume that every household will connect to an

⁵ If the water source is outside the home, the household may still have to pay for water, and, again, the estimate from the hedonic property value approach will be in addition to the household's payments. Similarly, a housing unit with good access to water vendors may command a premium in the housing market, but the household must still pay vendors for any water obtained.

improved system; yet the available indirect methods do not offer a simple, practical way of estimating how many households will, in fact, do so. For this we must turn to the contingent valuation method, in Chapter V.

V. Practical Approaches to Estimating the Economic Benefits to Households: Direct Methods (Contingent Valuation Surveys)

A. Introduction to Direct Methods

The contingent valuation method (CVM) offers a direct, intuitively appealing means of estimating the economic benefits of an improved water supply. Rather than attempting to infer from behavioral information how much an individual is willing to pay for improved service, one simply asks outright how much the individual or household would be willing to pay. This approach has several important advantages over indirect methods. First, it can be used to value services that are impossible to assess with indirect approaches. For example, it can be used to evaluate the benefits of increased reliability of existing water systems, or the reaction of households to prices or technologies beyond the range of past experience. Second, respondents' answers to willingness-to-pay (WTP) questions are easily understood by noneconomists and decision makers. The contingent valuation method does not necessarily require the use of sophisticated econometric techniques to derive estimates of economic benefits (though such techniques can be used concomitantly to provide more accurate estimates).

Of course, this direct approach has two obvious drawbacks: (1) the individual may not know how he (or she; or indeed the entire household) would react if offered the opportunity to use a new water system at a specified price; and (2) the individual may know but not tell the truth. In either case, whether or not respondents answer WTP questions accurately is an empirical problem. A later section of this chapter discusses ways of analyzing respondents' answers to increase confidence in their accuracy.

Some analysts see a third drawback to this direct question approach: someone must actually go out and talk to members of the community. Thus, project evaluation cannot simply be a desk job. In our view this perceived drawback is actually an advantage of the contingent valuation method, because it forces people in the government or their consultants to observe the current water situation and see what services people really want and are willing to pay for.

There is no perfect way of estimating household demand for improved water services, and investment, pricing, and management decisions must often be made in the face of considerable uncertainty about household demand. We believe that the contingent valuation approach can often provide useful (even if not perfect) information for decision making. This chapter describes how the contingent valuation method can be used to obtain estimates of the economic benefits of improved water services to households. Although, to date, the method has not been used to assess the benefits of improved water services to industries and commercial establishments, there is no reason why this could not be done.

B. Designing Willingness-to-Pay (WTP) Questions

Contingent valuation surveys are typically based on either of two types of WTP questions. (1) Respondents may be asked a direct, open-ended question such as: "What is the maximum amount of money you would be willing to pay (for a specified good or service)?" Or (2) respondents are presented with a specific choice which requires a yes/no answer: for example, "Suppose a water distribution line were installed in front of your house. Assume the connection fee was x (in local currency), and that the monthly tariff (perhaps for a given volume of water) was y . Would you choose to connect to the new water distribution system?"

Either of these two question formats can be used to develop estimates of households' willingness to pay for improved water services. But the two formats yield two different types of data. Responses to direct, open-ended questions take the form of "point" estimates of households' WTP; that is, they elicit a specific estimate for each household in the sample. Answers to the yes/no questions provide less precise information: all that we know from a single respondent's answer is that the household would be willing to pay the specified amount (or presumably any lower sum).

Table 5.1 presents the six main options for using open-ended and yes/no questions in a contingent valuation survey. With options 1 and 2, the respondent is just asked one WTP question. Option 1 involves asking only a single direct, open-ended question. If respondents could always provide accurate, reliable answers to such a question, this clearly would be the preferred question format. Unfortunately, for a variety of reasons, this often seems not to be the case. It is often difficult to convey the notion of the "most" (or the maximum) that one would be (freely) willing to pay, that is, able to pay if willing to do so. Some respondents misinterpret direct, open-ended questions to mean "What is the most you would *like* to pay?" or "What is the most you think you *should* pay?" Both of these nuances are clearly not what is meant to be conveyed. Most of the available evidence from both developed and developing countries suggests that a question posed as an "either/or" choice (i.e., a yes/no format) is generally easier for the enumerator to explain and for the respondent to understand.

TABLE 5.1
Six Main Options for Structuring Willingness-to-Pay Questions

Respondent Is Asked One Question
Option 1 : Direct, open-ended question
Option 2 : A single Yes/No question
Respondent Is Asked Two Questions
Option 3 : A single Yes/No question, followed by a direct, open-ended question
Option 4 : Two Yes/No questions
Respondent Is Asked Three Questions
Option 5 : Two Yes/No questions, followed by a direct, open-ended question
Option 6 : Three single Yes/No questions

Option 2 is to ask a single yes/no question of each respondent, but to vary the price offered across respondents. In other words, some respondents would be asked whether they would choose the improved water service if the tariff were at one level, and other respondents would be asked the same question but for different levels. For example, if the sample size were 500 households, 50 randomly selected respondents might be asked whether they would choose the service if the price were US\$1, another group of 50 would be asked whether they would choose the service if the price were US\$2, and so on up to US\$10. All of the 500 respondents would thus receive one yes/no question with a price somewhere between US\$1 and US\$10. This is known as the "referendum method." (Note that in the example of Option 2 shown above, only one variable is allowed to change; thus, questions that specify both the tariff (y in our sample question above) and the connection fee (x) must leave one or the other of these variables constant.)

The analysis of the kind of data obtained from Option 2 requires that an econometric model be estimated which explains the respondents' yes/no answers as a function of a series of independent variables, including the price at which each respondent was offered the service. This "referendum" model can be estimated with probit or logit techniques, and has been used to derive estimates of households' willingness to pay for improved water service (see McConnell 1990; Cameron 1988; Briscoe et al. 1990).

Options 3 and 4 both involve asking the respondent two WTP questions. Option 3 is a combination of Options 1 and 2. Each respondent is asked a single yes/no price question, and the specified prices are varied across subsamples of respondents just as described above. After the respondent answers the yes/no question, he (or she) is then asked a follow-up, direct question regarding the maximum the household would be willing to pay for the service. Option 3 has an important advantage over either Option 1 or Option 2: it yields two distinct sets of data on respondents' willingness to pay for improved water services, each of which can be analyzed to develop estimates of households' WTP. Since the follow-up, open-ended question is asked second, there is no risk that asking it will influence the answer to the yes/no question. Responses to the yes/no question can be analyzed just as with Option 2.

Answers to the open-ended follow-up question can also be analyzed to elucidate the determinants of the respondents' WTP bids. In this case one of the determinants of a respondent's WTP bid will be the price that was offered in the yes/no question. Ideally, the price offered in the yes/no question should not influence the final answer to the follow-up, open-ended question, but this can be tested statistically in a multivariate model of the determinants of the WTP bids (Whittington, Smith, Okorafor, Okore, Liu, and McPhail 1992). Option 3 is generally considered to be one of the most desirable question formats for contingent valuation surveys.

Option 4, which involves two yes/no questions without follow-up, is known as an "abbreviated bidding game": the first question asks whether the respondent would pay x ; the second requests the query at some higher or lower price (x'). The two yes/no questions will define four categories for the WTP bids: (1) yes-yes, (2) yes-no, (3) no-yes, and (4) no-no. The respondent's answers to these two yes/no questions will determine which of these four categories the WTP bid falls into. For example, if the answer is yes to both prices offered, the respondent falls into the highest WTP category; if the answer to both is no, the respondent is in the lowest. The two yes/no questions in Option 4 allow the analyst to more finely discriminate the level of a respondent's WTP than the single yes/no question in Option 1.

However, it is always important to consider whether the initial price offered influences respondents' answers. With Option 4 one can vary the "starting point" (x , the initial price offered respondents) by setting the first question at a high price for one group of randomly selected respondents and a low price for another group. This creates a problem: now the four categories defined by the two yes/no responses are not the same for the two groups. Hence, answers from respondents who received a high starting point cannot be easily compared with answers from those who received a low starting point. For this reason Option 4 is generally a poor way to structure the WTP questions.

However, there is a way to modify Option 4 to test whether respondents' answers are influenced by the sequence of questions asked. This modified version requires two groups: Group 1, respondents who receive a low starting value; and Group 2, respondents who receive a high starting value. For both groups the question format has two steps:

Group 1: Low Starting Value

Step 1: Ask the low starting value. If the answer is no, stop; if yes, go to Step 2.

Step 2: Ask the high starting value (the initial price for group 2);
whatever the answer, stop.

Group 2: High Starting Value

Step 1: Ask the high starting value; if the answer is no, go to Step 2; if yes, stop.

Step 2: Ask the low value (the initial value for group 1); whatever the answer, stop.

The result of this question format is that some respondents answer one yes/no question and others answer two. If L and H denote the low and high starting values, each respondent's WTP bid will fall into one of three categories: (1) $WTP < L$; (2) $L < WTP < H$; and (3) $H < WTP$. Because these categories are the same for both groups, the responses can be easily compared. This modified version of Option 4 is thus preferred to the "unmodified" version because it permits statistical testing to see whether the WTP bids of the two groups are different. Because there are three categories, multinomial logit analysis is generally the preferred multivariate technique for the analysis of the determinants of the WTP bids.

Option 5 can be termed the "abbreviated bidding game format with follow-up." Using the modified version of Option 4, Option 5 requires that a respondent answer either one or two yes/no questions and one direct, open-ended question:

Group 1: Low Starting Value

Step 1: Ask the low starting value; if the answer is no, go to Step 3;
if yes, go to Step 2.

Step 2: Ask the high starting value (the initial value for group 2);
whatever the answer, go to Step 3.

Step 3: Ask the respondent's maximum WTP for the service described.

Group 2: High Starting Value

Step 1: Ask the high starting value; if the answer is no, go to Step 2;
if yes, go to Step 3.

Step 2: Ask the low starting value (the initial value for group 1);
whatever the answer, go to Step 3.

Step 3: Ask the respondent's maximum WTP for the service described.

As with Option 3, there is little cost associated with asking the follow-up question, and here, too, we recommend asking it. Option 5 (using the modified version of Option 4) is one of the more desirable question formats.

Option 6 involves asking the respondent three yes/no questions. This question format, termed a "bidding game," was one of the first procedures used in the early development of the contingent valuation method. Table 5.2 presents an example.

TABLE 5.2
An Example of a Bidding Game (Option 6)

(Each respondent replies to exactly three questions. Prices and fees are expressed in US dollars as an arbitrary convenience.)

-
- (1) If the fee to connect to a water distribution line was US\$50, and the monthly tariff with an unmetered connection for an unlimited amount of water was US\$4, would you want to be connected to the water distribution system, or would you prefer to continue using your existing water sources?
 Yes - Connect Go to (2)
 No - Continue using existing sources Go to (5)
- (2) If the monthly fee was US\$6, would you want to be connected to the water distribution system, or would you prefer to continue using your existing water sources?
 Yes - Connect Go to (3)
 No - Continue using existing sources Go to (4)
- (3) What if the monthly fee was US\$7, would you want to be connected to the water distribution system, or would you prefer to continue using your existing water sources?
 Yes - Connect FINISHED
 No - Continue using existing sources FINISHED
- (4) If the monthly fee was US\$5, would you want to be connected to the water distribution system, or would you prefer to continue using your existing water sources?
 Yes - Connect FINISHED
 No - Continue using existing sources FINISHED
- (5) If the monthly fee was US\$2, would you want to be connected to the water distribution system, or would you prefer to continue using your existing water sources?
 Yes - Connect Go to (6)
 No - Continue using existing sources Go to (7)
- (6) If the monthly fee was US\$3, would you want to be connected to the water distribution system, or would you prefer to continue using your existing water sources?
 Yes - Connect FINISHED
 No - Continue using existing sources FINISHED
- (7) What if the monthly fee was US\$1, would you want to be connected to the water distribution system, or would you prefer to continue using your existing water sources?
 Yes - Connect FINISHED
 No - Continue using existing sources FINISHED
-

The principal advantage of Option 6 is that the series of three yes/no questions can be used to simulate a market-like bargaining process in which the enumerator raises or lowers the price depending on the respondent's answer. This feature of the bidding game format has proved to be of value in some developing countries. However, the available evidence

indicates that respondents' answers to later questions in a bidding game are conditioned on the starting value and the responses given to each previous question (this effect may also be present in Options 4 and 5). Thus, many analysts have concluded that little additional information is obtained by rapidly asking such yes/no questions.⁶ Most researchers and practitioners working with the contingent valuation method in industrialized countries have abandoned the use of the bidding game question format. Almost no one advocates asking more than three yes/no questions; most researchers now stop after one or two.

For developing countries, on the other hand, there is some anecdotal evidence that bidding games may be a useful approach for asking WTP questions. People in such areas are often quite comfortable with the bargaining style of a bidding game, and, in fact, may even be offended if the enumerator stops after venturing only one question. The appropriate question format for a specific site and culture must be based on judgment and experimentation.

C. Testing the Validity and Reliability of WTP Bids

1. Some Sources of Error in Contingent Valuation Studies

Many people—but particularly economists—are deeply skeptical about the validity and reliability of respondents' answers to hypothetical WTP questions. Two main kinds of concerns are at issue. The first is whether respondents will answer WTP questions honestly and accurately. The second is whether WTP responses are reliable measures of value. In this context reliability can be viewed either as the variance of a sample of WTP responses around the "true" mean WTP, or as the probability that a respondent's answer to a WTP question would be the same if he or she could be repeatedly tested (or asked the WTP question many times). If the reliability of WTP responses is poor, answers to WTP questions may be of little value, even though respondents did not intentionally give inaccurate answers.

Economists have long worried that if individuals actually had to pay their reported WTP values, then they would be tempted to understate their true preferences for public goods in hopes of a "free ride" while others pay for the provision of the good or service (Samuelson 1954). Alternatively, if the price to be charged for the public good is not tied to an individual's WTP response, but the provision of the public good is, the respondent may overreport WTP in order to ensure the provision of the good. In both cases the bid would be systematically different from the respondent's "true" willingness to pay. Literature on the contingent valuation method has termed this difference "strategic bias."

Systematic (that is, nonrandom) differences between respondents' answers to WTP questions and their true willingness to pay can arise for other reasons. Respondents in a particular cultural context may feel it inappropriate to answer some kinds of questions in specific ways or may attempt to give answers that they think will please the enumerator. This "compliance bias" can result in substantial differences between reported and true WTP values.

Differences can also occur because the description of the good or service and the terms under which it would be provided (the "CV scenario") may not convey what the survey

⁶ It is possible to design a contingent valuation survey that gives respondents time to think about their answers to WTP questions, and thus perhaps consider their responses more carefully. See Whittington, Smith, Okorafor, Okore, McPhail, and Liu 1992, for an example.

designer intended. This is not a "bias" introduced by the respondent, but an error introduced by the survey designer. It results from miscommunication: the respondent provides an answer to a question that the designer does not realize was asked or implied by the wording or format of the survey. If a significant number of respondents misinterpret the scenario, and reply in a similar way, this systematic error may distort the survey results.

The reliability of respondents' answers to WTP questions may be weakened in a number of ways. A respondent who does not know his willingness to pay and does not wish to exert the mental energy to think about his preferences may simply guess at an answer to a WTP question. If this is simply a random guess, such behavior would increase the variance of WTP bids in a sample of respondents without changing the expected value of the mean or "true" WTP. If there is a pattern to these guesses, perhaps derived from cultural norms or customs, such "hypothetical bias" may be introducing systematic errors into the WTP bids.

One often overlooked source of unreliability in aggregations of WTP responses is sampling error. Many contingent valuation studies reported in the literature have used quite small sample sizes, such that the results can be generalized to the population only with wide confidence intervals. Poor, nonrandom sample selection procedures may likewise introduce systematic biases into a study.

Despite these potential pitfalls, recent assessments of contingent valuation studies suggest that self-reported preferences from WTP questions for goods and services with *use value* (such as water and sanitation services) are generally much more reliable than economists have traditionally thought (Mitchell and Carson 1989). In particular, research findings from a large number of studies in industrialized countries fail to support the hypothesis that respondents will act strategically when answering WTP questions. Recent contingent valuation studies in developing countries have similarly demonstrated that respondents in both urban and rural locations give apparently reasonable answers to WTP questions about improved water services and that these answers are systematically related to their socioeconomic characteristics (Whittington, Briscoe, Mu, and Barron 1990; Briscoe, de Castro, Griffin, North, and Olsen 1990; Whittington, Smith, Okorafor, Okore, Lui, and McPhail 1992; Altaf, Whittington, Jamal, and Smith 1993).

There is little evidence yet, however, that such conclusions about the absence of strategic bias can be generalized to other developing countries or to different cultures. It is thus essential when conducting contingent valuation surveys in developing countries (as well as in industrialized countries) that the analyst design the study so that tests can be made to determine whether WTP responses appear accurate and reliable. Such tests are rarely conclusive, because there is no verifiable "true" value of WTP against which the answers to contingent valuation questions can be judged. Nevertheless different testing procedures can increase one's confidence in the results of contingent valuation studies and their usefulness.

2. Tests Based on Different Questions for Different Subsamples

Experimental design procedures can and should be used to detect whether different subgroups in the overall sample respond to changes in the survey instrument in the way one would expect. Discussions earlier in this chapter illustrated one such variation in the survey instrument: one group of sample respondents received a high starting price and another received a low one. Statistical tests can be conducted to determine whether "starting point bias" influences respondents' final bids.

Literature on the contingent valuation method has proposed numerous other variations in the survey instrument to test the accuracy and reliability of WTP bids. The following are examples:

- a. Variations in the elicitation procedure (that is, the way the WTP questions are asked). Some respondents might receive a single yes/no question with follow-up; others might receive only a direct, open-ended question.
- b. Variations in the order of the WTP questions. For example, if all respondents are to be asked their willingness to pay for both a public tap and a private connection, some might be asked about public taps first, whereas others would be asked about public taps second. (One would not expect the question order to influence the WTP bids.)
- c. Variations in the amount of time respondents have to reflect on their answers to WTP questions. For example, some might be asked all the WTP questions during a single interview; others might be asked questions over two interviews (allowing them time to think about their WTP responses).
- d. Variations in the description of the goods and services. For example, one subsample might receive a scenario description that would encourage strategic behavior; the wording received by another subsample would discourage strategic behavior.

Sometimes variations in the survey instrument are designed to induce a bias (such as the starting point bias test above); if the bias does not occur, that is good news for the accuracy and reliability of the WTP bids. In other cases, when the analyst tailors the variation to evoke a certain response, its absence is bad news. For example, one subgroup of respondents might be asked their willingness to pay for a private connection that would have good pressure four hours per day; another group could be asked their willingness to pay for a private connection that would have good pressure twenty-four hours per day. If respondents value the reliability of the water system, one would expect them to bid more for the more reliable water system. If the results do not confirm this hypothesis, the analyst will realize that further investigation is needed.

Testing for accuracy and reliability of WTP responses through such experimental design procedures can thus be quite tricky and requires considerable care in survey design. It is often a much more subjective process than many analysts would like to admit. For example, several early studies in the contingent valuation literature introduced variations in the method of payment for the good or service offered. The assumption was that respondents would be indifferent about modes of payment. When the surveys revealed that individuals were, in fact, *not* indifferent, the analysts claimed to have discovered a "payment bias" in responses to contingent valuation questions. On further reflection, most researchers concluded that this was not in fact a "bias" but rather a legitimate preference regarding the way people wanted to pay for a good or service. People in developing countries often have strong preferences about the way they want to pay for water. They often do not want to pay for water in advance, either because they are afraid that they will never get it, or for very sensible cash flow reasons (Whittington, Okorafor, Okore, and McPhail 1990).

3. Comparison of Results of Contingent Valuation Surveys and Indirect Benefit Analysis

For many economists the most compelling evidence of the accuracy of WTP bids from a contingent valuation survey is how closely they dovetail with benefit measures obtained from indirect valuation methods, such as the hedonic property value method described previously in Chapter IV. If time and resources permit, such comparisons are certainly useful. But it must be remembered that both direct and indirect measures of benefits have their limitations, and indirect measures should not be used simply as a criterion against which contingent valuation estimates can be judged. Both should be considered approximations of the "true" WTP value, and just how a comparison of such estimates should be evaluated remains a matter of professional judgment.

A comparison of benefit estimates from contingent valuation surveys and hedonic property value models will often be one of the most practical tests of this type that the analyst can conduct because much of the required data can be collected from the same household survey. Particularly in urban areas, respondents can be asked not only about their willingness to pay for an improved level of water service but also about the effect of improved water services on rental or property values. It is important to recognize that these are related but not identical questions, and that the benefit estimates derived through these two approaches actually measure slightly different theoretical concepts and cannot be directly compared (Brookshire, Thayer, Schulze, and D'Arge 1982).

It is also important to remember that one of the advantages of contingent valuation surveys is that they can often be used in situations where no other valuation method is practical. It is thus not always possible to undertake a comparison of direct and indirect valuation methods, even if sufficient resources are available.

D. Simple Approaches for Using the WTP Bids to Develop Estimates of Economic Benefits

Increasingly sophisticated econometric techniques are now being routinely used to analyze the determinants of WTP bids. These econometric analyses are necessary to learn the maximum amount from the survey data. Nevertheless, much can often be learned about prospective economic benefits by a careful examination of the frequency distribution of the WTP bids. Our objective here is to explain two simple procedures that can be used to develop such estimates using WTP bids obtained from a contingent valuation survey. Measures of economic benefits can also be obtained from yes/no responses to contingent valuation questions using econometric techniques, but these approaches are not reviewed here (see, for example, McConnell 1990; Cameron and James 1987).

Three steps are involved in estimating economic benefits to a community:

1. Determine the number of households that would use the improved water source at the specified set of prices charged by the water utility.
2. Estimate the benefits to a household (or to particular classes of households) of using the improved water source.
3. Aggregate the economic benefits to all households that will use the improved water source.

Contingent valuation information can be used in two basic ways to perform this three-step sequence without the use of econometric techniques. The first approach uses WTP bids both (1) to predict the number of households that would use the improved water source, and (2) to estimate the economic benefits to a household of using the improved source. The second approach uses WTP bids only to predict the number of households that would use the improved source; the economic benefits to a household are estimated using the c-factor procedure suggested in Chapter IV. The choice between these two approaches will usually depend on exactly what WTP questions can be meaningfully asked of respondents.

1. Approach 1: Using WTP Bids to Estimate Both Usage of an Improved Source and the Benefits to a Household

The first approach is feasible if the WTP bids are designed to elicit the maximum amount a household is willing to pay per month, either through a direct WTP question or through a bidding game, for the right to obtain as much water as desired from either (1) a new system of public taps in the community, or (2) an *unmetered* connection to a piped distribution system (possibly excluding the use of water for irrigation or resale to other households). In this case a respondent's WTP bid measures the total economic benefits to the household: the cost savings on the initial quantity of water consumed plus the consumer surplus on the increased water use resulting from a switch to an improved water source.

It is not necessary to know how the respondent's household intends to use the water from the new source, or the quantity of water to be used. For example, one respondent may offer a WTP bid for access to a system of public taps in a village and yet have no intention of using this water for washing, whereas another may offer a similar bid anticipating that his household would use such water for all household needs. In both cases the bid offers an appropriate estimate of the total economic benefits to the household.

All households whose willingness to pay is equal to or greater than a specified price (charged by the utility) are assumed to use the improved water system. The total economic benefits of the improved water source may then be obtained by aggregating the WTP bids from those households. For example, suppose that in a small community of 100 households, each household is asked its willingness to pay per month for an unmetered private connection to a new piped water system. Figure 5.1, the frequency distribution of their responses, shows that WTP varies from a low of US\$1 to a high of US\$5 per month.

Figure 5.2 shows the number of connections to the piped system as a function of the price charged by the water utility. If the water utility were to charge US\$4 per month for the connection, and under our assumption that only households that bid that much or higher would connect, we may posit that 30 households would choose to connect.

If instead the water utility sets the monthly price for a connection at US\$3, 70 households would connect to the piped system. The economic benefits of providing the piped water system are then the sum of the WTP of all these 70 households.

Note that these 70 households appraised the potential benefits differently. Forty households judged their benefits (stated their WTP) to be US\$3 per month; another 20 households judged their benefits to be US\$4; the remaining 10 households judged their benefits to be US\$5 per month. The total monthly economic benefits of the piped system to the 70 households can be calculated as follows:

Total monthly economic benefits of the system = Sum of the benefits of those households assumed to connect
 = $(40 \times \text{US\$3}) + (20 \times \text{US\$4}) + (10 \times \text{US\$5})$
 = US\$250 per month.

At an actual fee of US\$3, these 70 households must pay the water utility US\$210 per month. Their net economic benefits are thus US\$40 per month.

FIGURE 5.1
 Frequency Distribution of Maximum Willingness-to-Pay Bids for a Private Water Connection

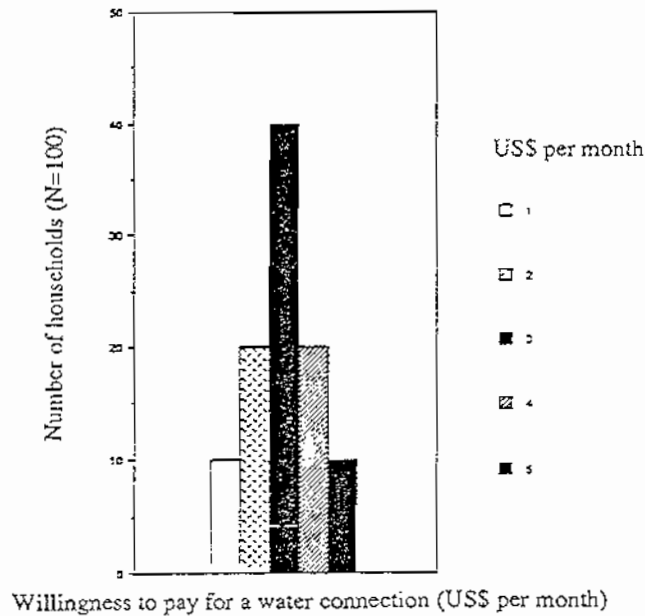
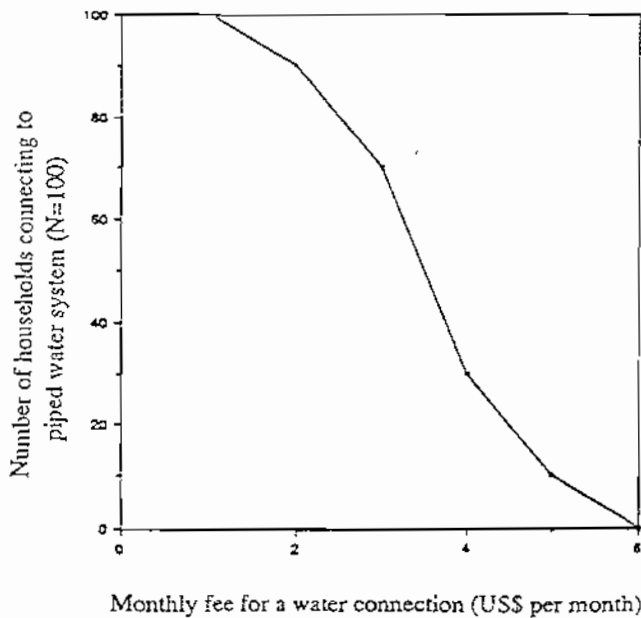


FIGURE 5.2
 Monthly Fee for a Water Connection vs. Number of Households Connecting to Piped Water System



2. Approach 2: Using WTP Bids to Estimate Usage of an Improved Source and C-Factors to Estimate the Benefits to a Household

This second approach uses WTP bids only to estimate the number of households that would connect to a new piped water system. This approach is most useful when the water utility intends to offer households the option of connecting to the new water system and having a metered private connection. In this case the WTP questions are designed to determine whether the household would connect to the new system if the price of water from the metered connection were set at a given level. The respondent may also be asked an open-ended question such as "What is the maximum price per cubic meter that your household would be willing to pay?"—that is, "If the price were higher than this, would you choose not to have a metered connection to the piped distribution system?" Just as in the first approach, answers to such questions can be used to estimate the number of households that would connect to the water system. But they cannot be used to estimate the economic benefits to the household, because the respondent does not provide any information on the quantity of water that the household would purchase at the maximum price. (In any case, it is usually impossible for individuals to provide meaningful answers to questions about the quantity of water they and other members of their households would use from a piped system at a specified price.) Thus, the WTP bids cannot be used to estimate the economic benefits to households without resort to sophisticated econometric methods. An alternative means is needed for rapid project appraisal work: the following example shows how.

Suppose that in our hypothetical community of 100 households each is asked its maximum willingness to pay for a cubic meter of water from a metered connection to a new piped distribution system. The frequency distribution of their responses is given in Figure 5.3, and following the procedure described above for the first approach, one can calculate the number of piped connections demanded at alternative prices (Figure 5.4). Suppose that the water utility sets the price of water at US\$1.50 per cubic meter. According to Figure 5.4, 75 households would then connect to the distribution system.

We may now use the c-factor procedure described in Chapter IV to estimate the economic benefits to a household that connects to the water distribution system. Suppose that the analyst knows that each individual in the average household of five is presently buying 20 liters per capita (Q_1) from a vendor at a price of \$5 per a cubic meter (P_1): that is, total household consumption is 100 liters per day, or 0.1 cubic meter, for US\$0.50. The analyst estimates that the members of the average household will use 100 liters per capita (Q_2) if the household connects to the piped water system and the water utility charges US\$1 per cubic meter (P_2): that is, total household consumption will rise to 500 liters per day, or 0.5 cubic meter, for the same total expenditure of US\$0.50 per day. The analyst assumes that the household's water demand function will be log-linear.

For these values for P_1 , Q_1 , P_2 , and Q_2 , the c-factor for the log-linear functional form is 1. This means that the consumer surplus on the household's increased water consumption is equal to its cost savings on the original quantity of water used. The household's cost savings and consumer surplus on the increased consumption can be calculated as follows:

$$\begin{aligned}
 \text{Cost savings} &= (P_1 - P_2) \times Q_1 \\
 &= (5 - 1) \times (0.02 \text{ cubic meters per capita per day}) \\
 &= \text{US\$0.08 per capita per day, or} \\
 &= \text{US\$0.40 per household per day}
 \end{aligned}$$

FIGURE 5.3
Frequency Distribution of Willingness-to-pay Bids
for Private, Metered Water Connection

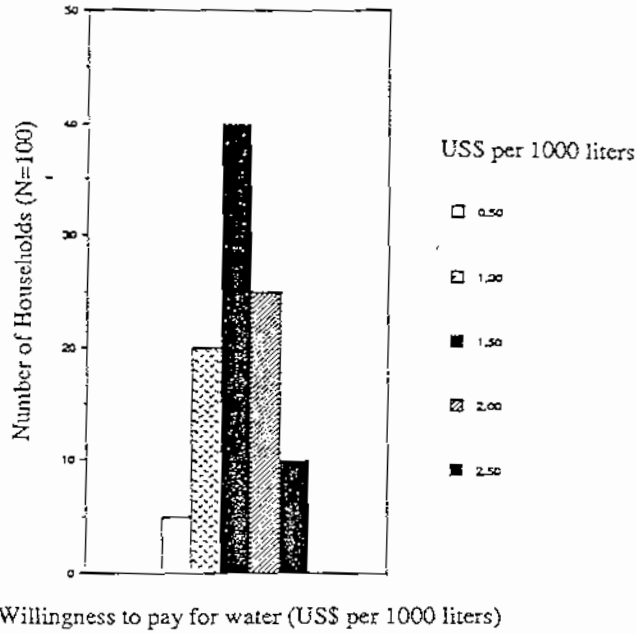
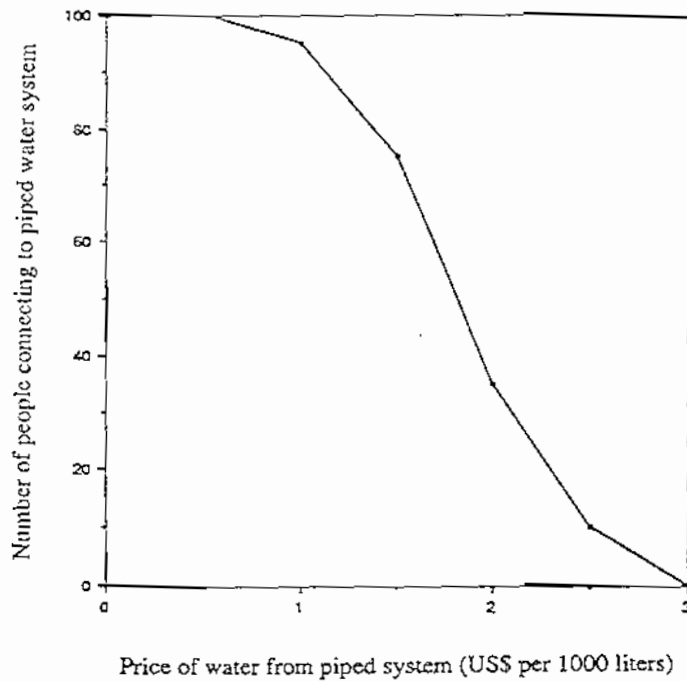


FIGURE 5.4
Price of Water vs. Number of Households
Connecting to Piped Water System



$$\begin{aligned}
 \text{Consumer surplus} &= c \times \text{Cost savings} \\
 &= 1 \times 0.08 \\
 &= \$ 0.08 \text{ per capita per day} \\
 &= \text{US\$}0.40 \text{ per household per day.}
 \end{aligned}$$

The household's net economic benefit from having the connection and purchasing Q_2 units of water at price P_2 is equal to the cost savings plus the consumer surplus on the increased consumption:

$$\begin{aligned}
 \text{Net economic benefits} &= \text{US\$}0.40 + \text{US\$}0.40 \\
 &= \text{US\$}0.80 \text{ per household per day.}
 \end{aligned}$$

The household's expenditures on water at P_2 must be added to the net economic benefits to obtain the total economic benefits (comparable to the estimates of economic benefits for alternative 1). The household's daily expenditures are

$$\begin{aligned}
 &= (Q_2 \times P_2) \times \text{the number of individuals in the household} \\
 &= 0.1 \text{ cubic meters} \times \text{US\$}1 \text{ per cubic meter} \times 5 \text{ individuals per household} \\
 &= \text{US\$}0.50 \text{ per day per household.}
 \end{aligned}$$

$$\begin{aligned}
 \text{Total economic benefits} &= \text{cost savings} + \text{consumer surplus} + \text{expenditures} \\
 &= \text{US\$}0.40 + \text{US\$}0.40 + \text{US\$}0.50 \\
 &= \text{US\$}1.30 \text{ per household per day.}
 \end{aligned}$$

The total economic benefits of the water project are obtained by multiplying the total economic benefits per household by the number of households that choose to connect: $\text{US\$}1.30 \times 75 \text{ households} = \text{US\$}97.50$ per day. Households would pay $\text{US\$}37.50$ of these economic benefits to the water utility, leaving the community with a net economic benefit of $\text{US\$}60$ per day.

VI. The Use of Benefit Information in Investment Planning

Up to this point we have focused on the question of how to estimate the initial (annual) benefits that households obtain from the introduction of water supply improvements. In this chapter we show how benefit information can be developed for use in a multi-period planning context. We examine two different situations: (1) one in which an improved water service is introduced into a community currently without a piped distribution system, and (2) one in which there is already a piped distribution system and the investment under consideration is intended to expand capacity and perhaps rehabilitate the existing facilities.

A. Introduction of a New Water System into a Community Presently Without Service

As with most investment projects, the construction of a new water supply system or an expansion of system capacity requires up-front capital costs followed by operation and

maintenance expenditures. After the project is completed, benefits accrue to households over the planning period. The calculation of the net present value of the project requires that both cost and benefit streams be discounted. The time profile of costs and benefits and the net present value calculation are shown in Table 6.1.

TABLE 6.1
Time Profile of Costs and Benefits

	Period 0	Period 1	Period 2	Period n
Benefits		B_1	B_2	$B_n + \text{Salvage Value System}$
Costs	Capital Costs	$O\&M_1$	$O\&M_2$	$O\&M_n$

Notes: Net Present Value of Project = Net Present Value of Benefit Stream - Net Present Value of Cost Stream

$$= [B_1 / (1+r)] + [B_2 / (1+r)^2] + \dots + [B_n / (1+r)^n] - \text{Capital Costs} + [O\&M_1 / (1+r)] + [O\&M_2 / (1+r)^2] + \dots + [O\&M_n / (1+r)^n]$$

The benefits accruing to households are depicted here as *total* benefits, i.e., the entire area under the relevant portion of the household demand curve. This includes any payments to the water utility or other suppliers of water. In the text benefits to households are presented as *net* of payments. This means that if the *benefits net of water payments* are used in the equations above, then the revenues to the water utility must be included as an additional benefit to the utility (or its shareholders).

The procedures described in the previous chapters show how the benefits to households in period 1 (B_1) can be estimated. How can the project analyst estimate the stream of benefits (B_1, B_2, \dots, B_n) over the planning period? One approach would be to simply assume that the annual benefits to households remain constant over the planning period ($B_1 = B_2 = \dots = B_n$). There are, however, two reasons why this assumption is unlikely to be true. First, if the community is growing and excess capacity is built into the water system so that it can serve the needs of the future population, then more households will be supplied with water at the end of the planning period than at the beginning. So even if the annual benefits *per household* remained the same, the aggregate annual benefits would increase.

Second, some of the determinants of *per household water demand* may change over the planning horizon. For example, household income or education level may increase. If household income is forecast to grow over the planning period (for reasons other than the provision of the improved water system), per household water use (and benefits) will grow because higher incomes generally entail higher water use. The analytical frameworks described in the previous chapters can be used to incorporate the effect of such changes on the annual benefits to such households.

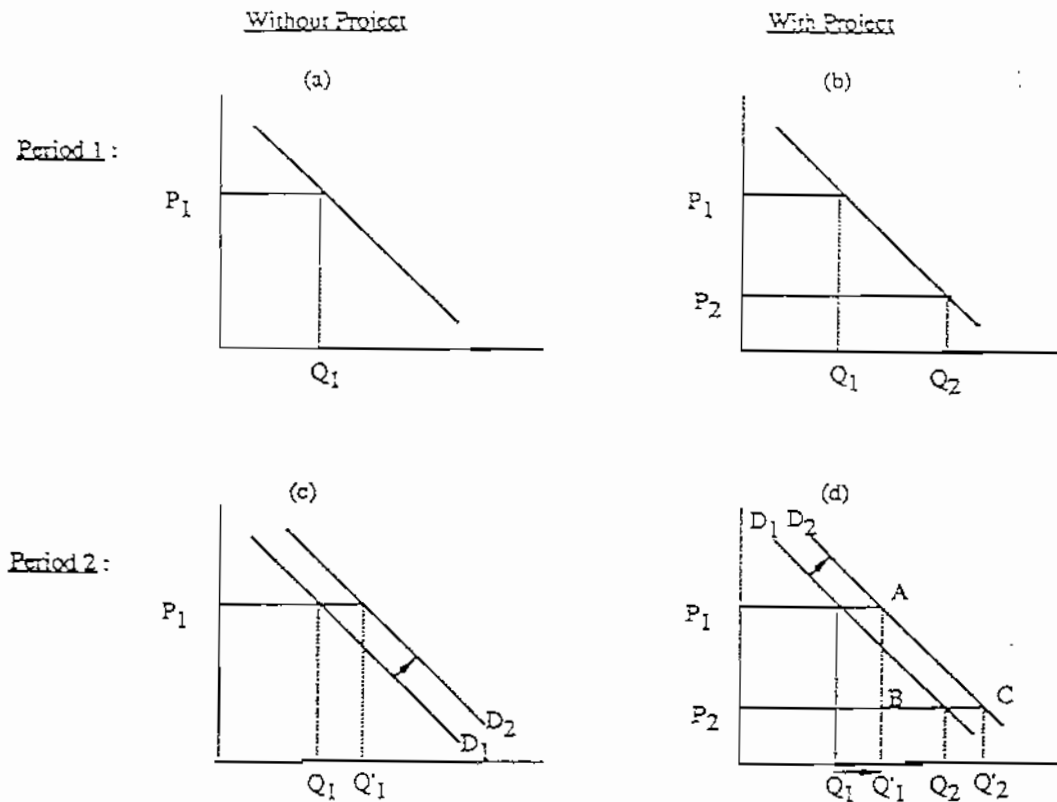
To address the question of how to estimate the stream of project benefits over time (B_1, B_2, \dots, B_n), it is useful to distinguish between three groups of households that may be affected by the project: (1) households that live in the community during period 1 and decide to connect to the new system as soon as it becomes operational (Group A); (2) households that live in the community during period 1 but decide not to connect to the new system when it first becomes operational (Group B); and (3) households that do not live in the community

during period 1 but move there sometime later in the planning period (Group C). If B_t^i = benefits to households in Group i in period t , then the annual benefits in period t are the sum of the benefits to households in each group in that period: $B_t = B_t^A + B_t^B + B_t^C$.

1. Households Living in the Community and Who Connect to the Water System in Period 1 (Group A)

Consider first an individual (household) in Group A and its water demand curves depicted in Figure 6.1a-d. If the new water system had not been built in period 1, the individual would have used Q_1 units of water and had to pay P_1 per unit (Figure 6.1a). If the new water system is built, in period 1 the individual connects and increases his water use to Q_2 , paying P_2 per unit (Figure 6.1b). His benefits in period 1 are the cost savings $[(P_1 - P_2) Q_1]$ plus his consumer surplus on the increased quantity of water used.⁷ As discussed in previous chapters, these can either be estimated using a contingent valuation survey and asking the individual his monthly willingness to pay for the introduction of the new system at price P_2 , or using indirect methods, such as the c-factor procedure presented in Chapter IV.

FIGURE 6.1
The Effect of an Increase in Income on an Individual's (Household's) Water Use



⁷ Annual household benefits are obtained by multiplying the daily benefits to the average individual in the household by the number of individuals in the average household, by 365 days per year.

Now suppose that from period 1 to period 2 the individual's income is forecast to increase (again, for reasons independent of the provision of the improved water system). This results in a rightward shift in the demand curve (from D_1 to D_2 in Figures 6.1c and d). If the improved water system is *not* built, the individual's water use would increase from Q_1 to Q_1' (Figure 6.1c)—assuming the quantity of water supplied from traditional sources can be increased by a modest amount. If the improved water system is built, the individual's water use would increase from Q_2 to Q_2' (Figure 6.1d). The benefit to the individual of the improved water system in period 2 is the difference between these two cases. This is the cost savings on the quantity he *would have purchased* [$(P_1 - P_2) Q_1'$] given his increased income plus the consumer surplus on the increased quantity of water used at the higher income level (area ABC in Figure 6.1d).

To estimate the benefits in period 2, we can again make use of the c-factor procedure. Since P_1 and P_2 are known, we first need to estimate Q_1' and Q_2' . This can be done by assuming a specific demand curve or assuming values on an ad hoc basis. Q_1' is the quantity of water that would have been used from the traditional source if income increased and the new water system was not built. There is almost no empirical evidence in the literature on the income elasticity of demand for water from traditional sources or water vendors (Whittington and Choe 1992), and the analyst will typically have to make a somewhat arbitrary assumption about how water use from the traditional source would have increased in response to an increase in household income.

Q_2' is the quantity of water that the individual would use from the improved system if price P_2 were charged per unit, and income increased as forecast. The literature on the income elasticity of demand for water from piped systems in developing countries is again very limited, but a value of 0.4 appears reasonable (Katzman 1977, Hubbell 1977, and Meroz 1968). In other words, if the individual's income increased by 10 percent from period 1 to period 2, his water use would increase by about 4 percent.

The next step is to use the values of P_1 , P_2 , Q_1' , and Q_2' to calculate the c-factor for period 2 from the relevant equation in Appendix 1. This requires an explicit assumption regarding the functional form of the demand curve. (Note that the c-factor in period 2 is *not* the same as in period 1.) The c-factor can then be used to estimate the consumer surplus on the increased quantity of water used in period 2 ($Q_2' - Q_1'$) for a household in Group A. To obtain an estimate of the benefits to all households in Group A in period 2, the analyst simply needs to multiply this *per household* amount by the number of households expected to be in Group A.

In practice the analyst will not have enough information to justify making such calculations for every year of the planning period. Instead, we suggest that this procedure be used to estimate the annual benefits to households in Group A at the end of the planning period (and perhaps one or two other periods in between period 1 and the last period), and then interpolate between these two amounts to obtain approximations of annual benefits for each year of the planning period.

To illustrate the calculation, suppose that before the installation of a new water system, an individual was buying 20 liters per day (Q_1) from vendors at a price of US\$2 per cubic meter (P_1). After obtaining a private connection to the new system, we assume that the individual would use 130 liters per day (Q_2), paying US\$0.25 per cubic meter (P_2). We estimate a cost savings to this individual of US\$0.035 per day, and, using the c-factor procedure and assuming a log-linear demand function, the consumer surplus on the increased water use would be US\$0.04 per day. The benefits to the individual in period 1

would be US\$0.075 per day, and the annual benefits to the household (assuming 6.5 people per household) would be about US\$180.

Now suppose that we assume a 20-year planning horizon and expect real incomes to double over this period. Assume that the income elasticity of demand is 0.4. This would imply that Q_2' would increase from 130 liters to 182 liters by the end of the planning period (assuming the real price of water from the system remains constant). Suppose that as a result of a doubling of income Q_1' would have increased to 30 liters per capita per day. In this case both the cost savings and the consumer surplus would be about US\$0.05. The benefits to the individual in period 20 would be US\$0.10 per day, and the annual benefits to the household in period 20 would be about US\$237. In this example we would suggest that a reasonable estimate of the time profile of benefits to a household in Group A would be to start at US\$180 in period 1 and increase the benefits by US\$3 per year over the planning period (i.e., $B_1 = 180, B_2 = 183, B_3 = 186, \dots$).

Another reason that the annual benefits occurring to households in Group A may change over time is that they might leave the community. If they are property owners, they may then receive a portion of the capitalized value of the water services in increased value of their property. If they are renters or if the value of water services is not capitalized into property values, then such households will obviously cease receiving benefits.

2. Households Living in the Community and Not Connected to the Water System in Period 1 (Group B)

Some households currently living in a community may not be able to afford to connect to the new water system immediately after it is installed, but may do so sometime over the planning period. In this case the analyst's task is twofold: (1) to estimate *when* these households will connect to the system, and (2) then to estimate the magnitude of their benefits and include them in the project's time profile of benefits after that point. Two distinct approaches are available to estimate *when* (if ever) a household will connect to the new system.

The first, ad hoc approach is to simply assume that some portion of the households in Group B will connect over the planning period and that connections will occur at some assumed rate. For example, suppose the analyst estimates that 30 percent of the households in the community will not connect to the system when it first becomes operational. If it is then assumed that 80 percent of these Group B households (24 percent of the total) would connect from period 2 to period 11 of the project, then it might be reasonable to assume that 8 percent of the Group B households would connect in period 2, 8 percent in period 3, and so on through period 11. This approach has little to recommend other than practicality and ease of implementation.

The second approach is to use forecasts of income (or other socioeconomic variables) and the results of a contingent valuation survey to predict when the willingness to pay of households in Group B will reach a level high enough to justify connecting to the system at the price charged by the utility. For example, suppose the analyst estimates a multivariate model of the determinants of the willingness-to-pay bids:

$$\begin{aligned} WTP_{bids} &= f(\text{Income, Education, Characteristics of Existing Water Source}) & (6-1) \\ WTP_{bids} &= \alpha_1 + \alpha_2 \text{Income} + \alpha_3 \text{Education} + \alpha_4 (\text{Water Source Characteristics}) + \epsilon \end{aligned}$$

If forecasts of changes in income, education, or other socioeconomic variables are available, then these forecast values can be inserted into the above equation and values of households' willingness to pay in future time periods can be derived. The predicted WTP bids of households in Group B would presumably be lower than those of households that connected immediately. However, as the incomes of Group B households rise, the model would indicate how much their willingness-to-pay bids would increase. The analyst can then make an estimate of when the different households in Group B might decide to connect to the system.

Using this approach, the actual time profile of when Group B households would be assumed to connect would be dependent on the forecast of their income and socioeconomic characteristics. The households initially not connecting might have a socioeconomic profile far below that of households connecting, and thus we would not expect them to connect early in the planning period, if at all. Alternatively, there may be few socioeconomic differences between Group A and Group B households, in which case the majority of Group B households might connect to the system very quickly.

After households in Group B are forecast to connect, the analyst must then estimate the magnitude of their benefits. This can again be done using either the contingent valuation results or the c-factor procedure. There is, however, a risk of introducing an inconsistency in the analysis at this point. If a household in Group B does not connect initially because the benefits of a connection are less than the price charged by the utility, then when the household finally does decide to connect, economic theory would suggest that its net benefits would be small, i.e., it would connect when the utility it derives from the connection is just greater than the utility from *not* connecting. So the model of the determinants of the contingent valuation bids would suggest that after a Group B household connects, its net benefits would be near zero.

On the other hand, the c-factor procedure might easily attribute large cost savings and consumer surplus benefits to such a household. The analyst must use his or her judgment in deciding which procedure is most likely to be appropriate in a specific case. Both procedures have limitations. The contingent valuation results may fail to capture the complexity of the capital constraints facing a household; in particular, a household may not be able to obtain the credit to finance the initial costs of a connection, even though the monthly cost savings may be relatively large. The c-factor procedure may fail to depict the value to a household of the cash flow flexibility provided by existing sources.

3. Households Not Living in the Community but Move In During the Planning Period (Group C)

Households that move into the community during the planning period will generally receive some benefits from the new water system, but the analyst must be careful not to count as benefits to Group C households those benefits already attributed to households in Groups A and B. The issue arises when the benefits of water services are capitalized into the values of the property of existing residents (Group A and possibly Group B) and the costs of financing these services are not similarly capitalized. This situation could arise, for example, if the capital costs of a water system were largely paid for with grants or subsidized credits from the central government or donors. If such differential capitalization occurs, and a household still decides to move into the community, then, clearly, on balance the household judges the attributes of the community (including the access to improved water service) to be worth the price of the property (or the rental value of a housing unit).

It is possible, however, that the higher purchase or rental prices may have captured much of the household's consumer surplus associated with the improved water services.

In this case the net (remaining) benefits of the improved water services to some of the Group C households may be quite small. The value of the time stream of services provided by the water system is effectively captured by existing property owners in higher property values. To the extent that the preferences of Group C households for improved water services are similar, much of their consumer surplus may be captured by existing property owners in higher prices (and rents). If there are substantial differences between households in Group C regarding their preferences for improved water services, then some of the Group C households may still obtain some consumer surplus over and above the value the property and housing markets attribute to the improved water services. In general, one would expect urban land and housing markets to capitalize at least some of the benefits of infrastructure services such as water. Similarly, it is quite common in the water sector for projects to be financed by grants or subsidized credits, and thus one would not expect the costs of the project to be capitalized in property values.

On the other hand, if the benefits of water services are not capitalized in rental and property values, then they can be fully appropriated by new residents. This might be the case, for example, in a situation where sufficient excess capacity was built into the water system to provide for new residents, and the government distributed vacant land at a fixed price to in-migrants (or squatters simply took vacant land). In this case the benefits to new residents can be estimated just as for Group A or Group B households, using either the contingent valuation method or indirect methods. The benefit estimates can be improved if a detailed socioeconomic profile of existing and future in-migrants is available.

B. Benefits of a Project Designed to Expand System Capacity

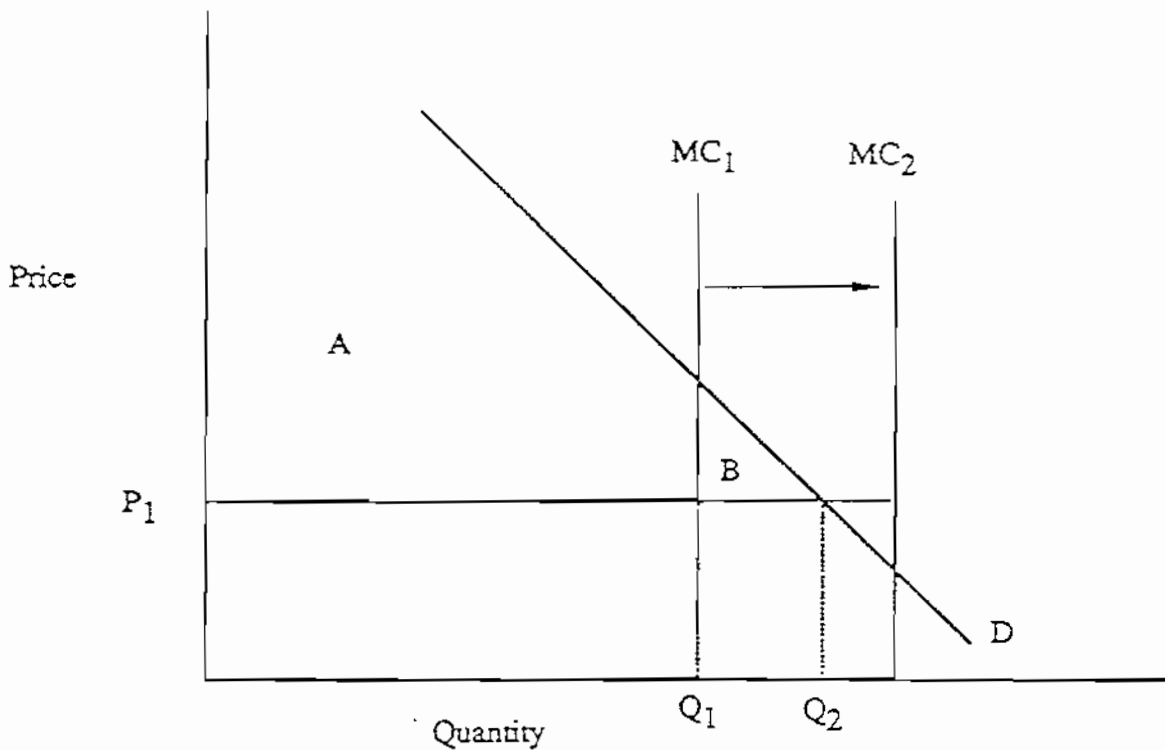
It is considerably more difficult to estimate the benefits of a water supply project designed to expand system capacity than the existing literature on the economic appraisal of such water supply projects would suggest (Powers 1980; Powers and Valencia 1980). System capacity expansion projects benefit houses that already have connections to the old piped system, as well as the same three groups of households described above. The benefit estimation procedures for Groups A, B, and C are no different from that for a new water supply project because in all three cases households are obtaining a connection in the community for the first time. The problem arises in estimating the benefits to households that already have a connection and are receiving water from the old distribution system (we term these "Group D households").

Suppose that before the system expansion an amount of water Q_1 is available to Group D households at a price P_1 .⁸ At this price there is, however, an excess demand for water; Group D households actually demand an amount of water Q_2 . If it were possible for the water utility to actually ration the quantity of water Q_1 and deliver it in such a way that only the highest value uses of water by Group D households were supplied (and Group D households were provided with reliable service to meet these needs), then *before* the system expansion the Group D households would receive a consumer surplus (area A in Figure 6.2) equal to the area under the demand curve from 0 to Q_1 minus their expenditures ($P_1 \times Q_1$).

⁸ Note that we now shift our focus from the individual's (household's) demand curve to a market demand curve—the horizontal aggregation of the demand curves of all the individuals (households) in the community.

As a result of the system expansion, the water utility's marginal cost curve shifts to the right (MC_2 in Figure 6.2). Group D households can now purchase all the water they want at price P_1 , and they buy Q_2 . In this case it would be a simple matter to calculate the benefits to Group D households from the project.⁹ These benefits would simply be the consumer surplus on the increased water consumption ($Q_2 - Q_1$) (area B in Figure 6.2).

FIGURE 6.2
Welfare Effects of a System Capacity Expansion



However, this is almost never an accurate description of the water supply situation facing such Group D households, because the water utility, in fact, cannot deliver water in such a way that only the highest value uses by Group D households are supplied. Water is typically rationed not by price, but by low pressure and supply interruptions. Because water systems in need of expansion in developing countries are typically plagued with reliability and distribution problems, Group D households do not actually receive a consumer surplus equal to area A in Figure 6.2.

⁹ We assume here and in Figure 6.2 that the price of water from the old and new distribution systems is the same.

Households often respond to unreliable supplies in either or both of two ways. First, households purchase or construct storage facilities so that they can collect water when the system is in operation in order to have water for use when the system is down. Second, households may install their own suction pumps to draw water out of the distribution system, thus lowering the pressure for others.

One of the main benefits of system capacity expansion and rehabilitation projects to Group D households is thus the increased *reliability* of their water supply, not simply the increase in the total amount of water available. Increased reliability can save households the expense of storage facilities, as well as the inconvenience and time lost dealing with chronic shortages. Increased reliability can thus be very valuable to Group D households—much more so than simply the consumer surplus on the increased quantity of water used. In effect, the system capacity expansion can allow Group D households to actually obtain the consumer surplus (area *A* in Figure 6.2) that is likely to be only a potential benefit if the existing system is unreliable.

The reliability aspect of a water supply system is typically lost in the depiction of a conventional water demand curve: it is implicitly assumed that all possible quantities are supplied with equal reliability. The c-factor procedure is thus unable to adequately address the value of a more reliable water supply to a Group D household. However, the c-factor can be used to get an upper bound estimate on the value of the system expansion to a Group D household. This can be done by estimating the potential consumer surplus on the existing quantity of water provided Q_1 (area *A* in Figure 6.2), and attributing it *all* to the capacity expansion. If the reliability of the existing system is very poor, this is likely to be a reasonable approximation.

Alternatively, the contingent valuation approach can be used to estimate the benefits to Group D households of improving the reliability of the existing quantity of water received. In this case a sample of Group D households would be asked their willingness to pay for some specified level of reliability (e.g., "What is the most your household would be willing to pay to ensure that water was available from your private connection 24 hours per day, every day of the week, with good pressure?").

This kind of question has been successfully used in a contingent valuation study conducted in the Punjab, Pakistan (Altaf, Jamal, and Whittington 1992; Altaf, Whittington, Jamal, and Smith 1993). In the study area households with private connections typically had water for only a few hours per day; they were asked how much they would be willing to pay per month for improved reliability. Their responses suggest that on average they would be willing to pay more than double the current tariff if reliability were improved. Also, some households that chose not to connect to the unreliable system would connect if reliability were improved.

If the time and resources are not available to carry out such a contingent valuation study, another alternative is to estimate the amount of time and money such households are spending to deal with the reliability problem. The cost savings that would result from improved reliability can be estimated. For example, estimates could be made of the proportion of households that have made expenditures for water storage facilities and the associated capital costs. In some cases such expenditures are quite substantial (Whittington, Okorafor, Okore, and McPhail 1990; Whittington, Lauria, and Mu 1991).

VII. Summary and Conclusions

In this paper we have argued that potable water supply projects need to be subjected to more rigorous economic analysis than is commonly required by most donor agencies. At its most fundamental level, economic analysis is important because it helps identify those projects that people want and for which they are willing to pay. Improved economic appraisal of water supply projects will result in better allocation of investment funds, better decisions on the appropriate level of service to be provided (e.g., public taps or private connections), and better decisions on the price to be charged households for improved service.

In order to improve the practice of economic appraisal in the water supply sector, analysts need to be familiar with the alternative approaches to benefit estimation and their strengths and weaknesses. This requires that project analysts understand some of the conceptual difficulties involved in developing better models of household water demand behavior. In Chapter III we reviewed the theoretical basis for benefit estimation in the water supply sector. We noted that in the standard paradigm there are two components of the economic benefits an individual receives from the installation of an improved supply: (1) the monetary cost of resource savings associated with the quantity of water used prior to the installation of the new system, and (2) the consumer surplus associated with the increased quantity of water used. We argued, however, that this standard paradigm is incomplete because it fails to adequately address the problem of *water source choice*. The benefits an individual receives depend upon whether or not he or she chooses to use a new source and on how much water is used from the new source (assuming it is chosen). This paper has paid special attention to ways of incorporating explicitly this discrete-continuous decision.

Some analysts have wanted better estimates of the economic benefits of water supply projects, but have concluded that it was too difficult to actually measure them. In Chapters IV and V we described several approaches that we believe are practical and can provide useful estimates of economic benefits. In Chapter IV we presented a two-step procedure to estimate the economic benefits to a household *if* it decides to use the new water supply system. The first step is to estimate the real resource cost savings to households of using their current source and use this information to estimate the cost savings obtained from the introduction of the improved water system. Improved water supplies can reduce water collection costs in terms of time, money, and energy—all of these savings have economic value.

Second, we outlined a simple procedure for developing estimates of the consumer surplus on the increased quantity of water used as a result of the fall of the shadow price (or real resource cost) of using water. We recommend simply assuming a functional form for the water demand function and estimating the quantity of water that is likely to be consumed at the price that is expected to be charged. Based on this information and knowledge of the current water use and shadow price, the demand function can be defined and the consumer surplus easily determined. In Appendix I we have provided the equations necessary to carry out these calculations.

In Chapter IV we also described another revealed preference approach to estimating benefits: the hedonic property value model. Using this indirect method, an analyst can infer the value households place on improved water services from the decisions they make about the housing they choose to live in. Although there are many situations where this hedonic

property value model will not be applicable, we believe that this indirect approach has considerable promise in developing countries. This is because housing markets in many developing countries are becoming less subject to restrictions such as rent controls, and because it is fairly easy to carry out a household survey to collect the data necessary to estimate the model.

In Chapter V we provided an overview of the contingent valuation method and discussed how it can be used to estimate the economic benefits of water supply projects. The contingent valuation method can be used in two different ways to develop an estimate of economic benefits. First, the answers respondents give to some kinds of contingent valuation questions are direct measures of economic value. Second, the answers to contingent valuation questions can be used just to estimate how many people in a community will choose to use a new water supply system (i.e., to predict households' source choice decision), and then indirect methods such as detailed in Chapter IV can be used to estimate the benefits to those households that do use the new system.

The contingent valuation method has several other important advantages. For example, it can be used to value aspects of water services, such as reliability, that are generally extremely difficult to assess with indirect methods. Also, respondents' answers to contingent valuation questions are easy for policy makers to interpret and understand. We stressed that analysts using the contingent valuation method must provide evidence that respondents' answers to hypothetical questions are accurate, reliable measures of economic value, and we discussed some of the tests necessary to increase one's confidence in the results of a contingent valuation survey. Chapter V also reviews the different ways that respondents can be asked willingness-to-pay questions in contingent valuation surveys.

Chapter VI shows how the information obtained from the benefit estimation procedures described in Chapters IV and V can be used in a multi-period planning context. We examined two different situations. First, we discussed communities that are presently without improved water service, and the project introduces a new water system (new level of service). Second, we examined communities with an inadequate distribution system and unreliable service, and the new water project expands system capacity and improves reliability. The evaluation of the first situation requires that the economic benefits to households in the following three groups be estimated and then summed:

- Group A* – households living in a community and who connect to (use) the new water system when it is installed;
- Group B* – households living in a community and who decide not to connect to (use) the new water system when it is installed;
- Group C* – households not living in the community when the water project is installed, but move in during the planning period and decide to use the new system.

The evaluation of the second situation requires the same information on these three groups, as well as information concerning one more group:

- Group D* – households living in a community and who already have a connection to the existing water system (or use an existing system of public taps or handpumps).

The main difference between estimating the benefits for Groups A, B, and C is simply the time period in which they begin to receive the benefits of the improved water system. We show in Chapter VI that additional issues arise in estimating the benefits to households in Group D, and suggest that the contingent valuation method be used to estimate the benefits of increased reliability and increased quantity of water to these households. If the time and resources are not available to carry out a contingent valuation study, we recommend that the analyst approximate the benefits to Group D households by estimating the time and money they are spending to deal with the reliability problem.

In conclusion, we believe that there is a clear need for both improved procedures and better practice in the estimation of the economic benefits of water supply projects. The selection of the appropriate benefit estimation approach to use in a given situation will depend on the time and budget constraints of the analyst doing the economic analysis. However, all of the recommended approaches discussed in this paper require at least some primary data collection at the household level. Household water demand behavior is sufficiently complex, and existing data on household water use are so limited that it is rarely advisable to rely solely on desk-top studies to estimate project benefits. Primary data collection (including household surveys) is thus necessary during project preparation and appraisal in order to improve the quality of benefit estimates. Once a commitment is made to undertake a household survey, it does not usually cost much more to obtain the information required to implement several (rather than just one) of the benefit estimation procedures described in this paper.

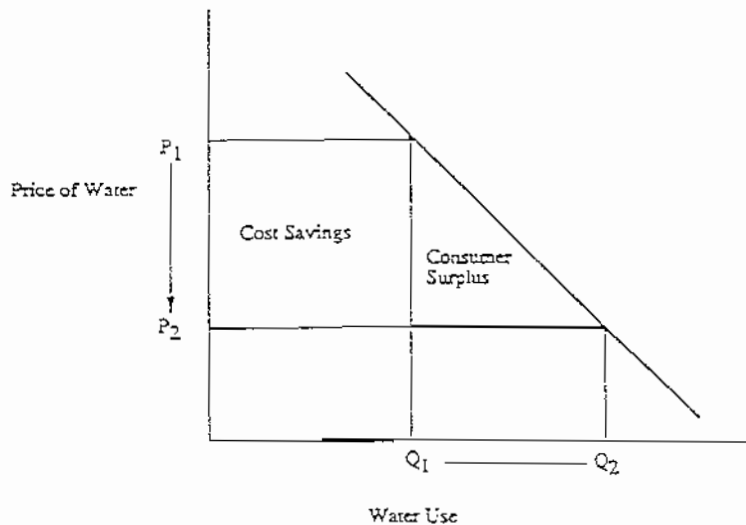
APPENDIX 1

Estimating the Consumer Surplus on Increased Water Use: The Use of C-Factors

A. Derivation of C-factors for Three Demand Functions

Figure A1 shows a hypothetical water demand function for a household aggregated over different water uses. Let the price of water charged by a distributing vendor be P_1 , and assume that the household's water consumption at P_1 is Q_1 . If the water utility supplies water at a lower unit price, say P_2 , then a household is expected to consume a higher quantity of water, Q_2 . The increased benefits to the household due to the decreased price of water may be split into two parts: (i) cost savings and (2) the consumer surplus on the increased water use.

FIGURE A1
A Hypothetical Water Demand Curve



Cost savings are defined as the difference between a household's expenditures at the vendor's price (P_1) and the utility's price (P_2), to obtain the quantity of water Q_1 . Consumer surplus is defined as the difference between a household's perceived total benefits due to the price change, and the cost savings. We define the "c-factor" as the ratio of the consumer surplus to the cost savings:

$$c = \frac{\text{Consumer Surplus}}{\text{Cost Savings}}$$

The purpose of this Appendix is to explain how "c-factors" can be calculated for a specific demand function and then to derive the mathematical expressions for them for three forms of the demand function: linear, exponential, and power (i.e., log-linear). These expressions for the c-factor enable the analyst to estimate the c-factor based on assumptions about the demand function and other parameters.

Cost savings do not change with the demand function assumed and can easily be derived before calculating the c-factor:

$$\begin{aligned} \text{Cost savings} &= \text{household water expenditures to obtain } Q_1 \text{ at a vendor's price, } P_1 \\ &\quad - \text{household water expenditures to obtain } Q_1 \text{ at a utility's price, } P_2 \\ &= P_1 Q_1 - P_2 Q_1 \\ &= Q_1 (P_1 - P_2). \end{aligned}$$

Because it is a relatively easy matter to calculate the cost savings, it is possible to estimate the consumer surplus on the increased quantity of water used once the c-factor is derived:

$$\text{Consumer surplus} = \text{c-factor} \times \text{cost savings.}$$

The general forms of the assumed demand functions can be stated as:

$$\begin{aligned} \text{Linear demand function} & : Q = a - bP \\ \text{Exponential demand function} & : Q = a e^{-bP} \\ \text{Power demand function} & : Q = a P^{-b}, \end{aligned}$$

where a and b are constants.

$$1. \text{ Linear demand function: } Q = a - bP$$

$$\begin{aligned} \text{Consumer surplus} &= \text{benefits obtained due to price change} - \text{cost savings} \\ &= \text{area under the inverse demand function between } P_2 \text{ and } P_1 - \text{cost savings} \\ &= \left[\int_{P_2}^{P_1} (a - bP) dP \right] - Q_1 (P_1 - P_2) \\ &= a (P_1 - P_2) - \left(\frac{b}{2} \right) (P_1^2 - P_2^2) - Q_1 (P_1 - P_2) \end{aligned}$$

When these terms are simplified,

$$\text{Consumer Surplus} = \frac{(P_1 - P_2)(Q_2 - Q_1)}{2}$$

and the c-factor can thus be given as

$$\begin{aligned} c &= \frac{\text{consumer surplus}}{\text{cost savings}} \\ &= \frac{(P_1 - P_2)(Q_2 - Q_1)}{2Q_1(P_1 - P_2)} \\ &= \left(\frac{1}{2} \right) \frac{(Q_2 - Q_1)}{Q_1} \end{aligned}$$

$$2. \text{ Exponential demand function : } Q = a e^{-bP}$$

$$\begin{aligned} \text{Consumer surplus} &= \text{benefits obtained due to price change} - \text{cost savings} \\ &= \text{area of the inverse demand function between } P_2 \text{ and } P_1 - \text{Cost savings} \\ &= \left[\int_{P_2}^{P_1} (a e^{-bP}) dP \right] - Q_1 (P_1 - P_2) \\ &= \frac{a}{b} (e^{-bP_1} - e^{-bP_2}) - Q_1 (P_1 - P_2) \\ &= \frac{1}{b} (Q_2 - Q_1) - Q_1 (P_1 - P_2) \quad \text{and} \end{aligned}$$

$$\begin{aligned} c &= \frac{\text{consumer surplus}}{\text{cost savings}} \\ &= \frac{1}{b} \frac{(Q_2 - Q_1)}{Q_1 (P_1 - P_2)} - 1 \end{aligned}$$

Note that this equation is not valid if P_1 is less than or equal to P_2 .

3. Power (Log-linear) demand function : $\ln Q = \ln a - b \ln P$, or $Q = a P^{-b}$

Consumer surplus = benefits accruing to a household due to price change - cost savings
 = area under the inverse demand function between P_2 and P_1 - cost savings

$$\begin{aligned} &= \left[\int_{P_2}^{P_1} (aP^{-b}) dP \right] - Q_1 (P_1 - P_2) \\ &= \frac{a}{1-b} (P_1^{1-b} - P_2^{1-b}) - Q_1 (P_1 - P_2) \\ &= \frac{1}{1-b} (P_1 Q_1 - P_2 Q_2) - Q_1 (P_1 - P_2) \quad \text{and} \end{aligned}$$

$$\begin{aligned} c &= \frac{\text{consumer surplus}}{\text{cost savings}} \\ &= \frac{1}{1-b} \frac{(P_1 Q_1 - P_2 Q_2)}{Q_1 (P_1 - P_2)} - 1 \end{aligned}$$

Note that this equation is not valid if P_1 is less than or equal to P_2 .

The c-factors change with different assumptions about water prices, water usage, and demand functions. Each of the three assumed demand functions contains two unknowns (a and b). Two data points are thus required to derive a specific demand function. The first corresponds to a household's water consumption (Q_1) at the vendor's water price (P_1). Usually this can be observed in the field. The second point is the household's water consumption (Q_2) at the water utility price (P_2). Given values of P_1 , Q_1 , P_2 , and Q_2 , one can construct a specific demand function using the procedure described above, and c-factors can be calculated using the appropriate equation.

APPENDIX 2

Guide to Estimating the Benefits of Potable Water Supply Projects

This appendix summarizes the approaches recommended in this paper to develop better estimates of the economic benefits of potable water supply projects to households in developing countries.

A. A Classification Scheme

In order to think systematically about the economic benefits of a water supply project, it is useful to consider two kinds of projects and four groups of households. First, there are new water systems in communities presently without service (Type I), and system capacity expansion projects in communities currently with an inadequate distribution system (Type II). Second, water supply projects affect four groups of households:

- Group A – households living in a community and who connect to (use) the new water system when it is installed;
- Group B – households living in a community and who decide not to connect to (use) the new water system when it is installed;
- Group C – households not living in the community when the water project is installed, but move in during the planning period and decide to use the new system; and
- Group D – households living in a community and who already have a connection to the existing water system (or use an existing system of public taps or handpumps).

The evaluation of Type I projects requires that the economic benefits to households in Groups A, B, and C be estimated and then summed (and discounted) to obtain the aggregate economic benefits to the community. The evaluation of Type II projects requires that the economic benefits be estimated for all four groups of households. The benefits estimation procedures for households in Groups A, B, and C are similar—the main difference is *when* during the planning period they begin to receive the benefits from the improved water system. Households in Group D face a somewhat different situation, and estimating their benefits requires additional considerations and a slightly modified approach.

B. Type I Projects (New Markets): Benefits to Households Presently Without Improved Water Service (Groups A, B, and C)

Four steps are required to estimate the economic benefits to households that are presently without improved water service.

Step 1: Determine Whether Households Will Use the Improved Water Source

The first step in estimating the benefits to households presently without improved water service is to determine whether or not households will use the improved system and, if so, when. Past appraisal methods have paid far too little attention to this step, assuming that all households in a community will use an improved water system if it is installed. This assumption has often resulted in overly optimistic forecasts of the number of beneficiaries of new water systems and overestimation of the benefits of the water project.

In order to estimate how many households will use an improved water supply system if a specified price is charged by the water utility, it is recommended that a household survey be carried out to elicit either the maximum amount a household is willing to pay per month for the right to obtain water

at a specified price, or the maximum amount it is willing to pay per unit of water. Water could be available, for example, from a private connection or a new system of public taps. This "contingent valuation survey" yields a frequency distribution of the willingness-to-pay responses which shows the percentage of households indicating that they would connect to (or use) the new water system at different prices (or monthly fees). Once the analyst determines the price to be charged for water from the new system, the percentage of households that can be expected to use the new system at this price can be determined.

Step 2 - Estimate the Benefits to a Household if It Does Use the Improved Water System

Three approaches are recommended as possible alternatives for estimating the benefits to a household—or particular classes of households—from using the improved water source. Each of the three methods has strengths and weaknesses, and the decision as to which to use in a particular case is a matter for professional judgment. Ideally, all three approaches would be used and the results compared with each other before reaching a determination of the economic benefits of the water project.

Approach 1 - The Contingent Valuation Method

The results of a contingent valuation survey can be used to estimate not only the number of households that will use the new system, but also their economic benefits. A household's willingness-to-pay bid is a direct estimate of the value of the improved water service to the household. In effect, the respondent is asked for his estimate of the magnitude of the cost savings and consumer surplus components of the benefits.

There are two main limitations of this "direct question" approach to estimating households' economic benefits. First, the respondent may not know how household members would react if offered the opportunity to use a new water system at a specified price, and thus may not know the "true" value of the improved water service to his household. Second, the respondent may know but not tell the truth. However, recent experience with the use of contingent valuation surveys in developing countries suggests that these problems are not as great as many people feared, and that much useful information about how households value improved water services can be obtained from carefully designed and executed household surveys.

Approach 2 - The Hedonic Property Value Model

This second approach is based on the insight that households reveal their preferences for improved water services in the prices they pay for housing—either in rent or the purchase price of their house. The objective of the hedonic property value approach is to obtain an estimate of the incremental amount that households would be willing to pay to have the improved water service, while controlling for other factors that affect the price of housing.

The hedonic property value model is most applicable to situations in which an improved piped distribution system is *already* installed and some households are connected to the system and some are not. Estimates are obtained from the hedonic property value model of how much different groups of households in this community benefit from the improved water system. These benefit estimates can then be *transferred* from this first community to another community where a new water supply project (or system capacity expansion) is being evaluated. The assumption must be made that households in these two communities value improved water services similarly (or that their valuation varies systematically with the socioeconomic characteristics of the households).

To implement the hedonic property value approach, it is recommended that the analyst estimate the hedonic price equation for different categories of sample households—e.g., low-income, middle income, and high-income households—in order to better group households with similar preferences for a piped connection, as well as similar preferences for other housing attributes (Quigley 1980). This will yield an estimate of each household category's willingness to pay for a private water connection, which can then be taken as a measure of the mean economic benefits to the average household for each category.

The analyst can then use the estimate of the number of households in each income category that will decide to use the improved service in the community that is being considered for a new water system (from Step 1), and approximate the total economic benefits to households in that category. This is done by multiplying the number of households in an income class (that are to be provided with service) by the economic value of the service for the average household in that income class estimated from the hedonic price equation.

The hedonic property value model assumes that (1) households can freely investigate available housing in different locations to find a unit with the best attributes, considering the price that must be paid, and (2) there is an active, competitive housing market. It is thus not appropriate in situations where rent controls are in effect or other factors distort the housing market.

Approach 3 - Calculate the Cost Savings and Assume a Water Demand Function in Order to Estimate the Consumer Surplus ("C-Factor" Method)

This approach requires that the analyst first calculate the cost savings component of the economic benefits, and then estimate the consumer surplus associated with the increased water consumption. The calculation of the cost savings component involves four simple steps:

1. Determine the shadow price (or real resource cost in terms of money, time, fuel, etc.) of a unit of water to households before the project is constructed (P_1).
2. Estimate the shadow price of water to households after the project is constructed (P_2).
3. Estimate the quantity of water households are using before the new water system is built (Q_1).
4. Calculate the cost savings per household by multiplying the difference in the shadow price of water before and after the project ($P_1 - P_2$) by Q_1 .

Values of P_1 and Q_1 can be obtained from a household survey, preferably the same contingent valuation survey used in Step 1 (and possibly approach 1 of Step 2). Values of P_2 may be estimated by the project analyst on the basis of cost recovery, financial, or economic pricing objectives.

To estimate the consumer surplus on the increased quantity of water used, a demand function for water is required. It is rarely possible, however, to obtain the kind of detailed household water use data necessary to estimate household water demand functions from simple household surveys. The project analyst will thus generally not be able to collect these data as part of a project appraisal exercise. Instead, an alternative is to simply assume a functional form of the water demand relationship and estimate the quantity of water that is likely to be consumed (Q_2) at the price to be charged (P_2). The forecast of the quantity of water to be used at price P_2 can be based on experience in similar communities that already have an improved system. Given the two points (P_1, Q_1) and (P_2, Q_2), and the assumption of a functional form, the demand curve can be defined over the relevant range of values of Q .

To assist the analyst with the calculation of the consumer surplus, we recommend the following procedure. First, calculate the cost savings $(P_1 - P_2)Q_1$. Second, determine the ratio of the consumer surplus to the cost savings (which we define as the "c-factor"). When calculating the c-factor, the analyst should use a log-linear functional form for the water demand curve unless there is empirical evidence to suggest that another functional form would be more appropriate. Third, multiply the c-factor by the cost savings to obtain an estimate of the consumer surplus.

An advantage of this c-factor approach is that it conveniently relates the magnitude of the consumer surplus to the cost savings, yielding separate estimates of each. The analyst should generally keep these estimates separate because the estimate of consumer surplus will typically be much more speculative than the estimate of cost savings.

Step 3 - Estimate the Time Stream of Benefits Over the Planning Horizon

The analyst must next determine how the magnitude of benefits to different groups of households from the use of an improved water system will change over the planning horizon. The analytical models developed in Step 2 and forecasts of economic and population growth are required for this task. After the

time profile of economic benefits *per household* has been developed for households in the different groups, the analyst multiplies the number of households forecast to use the new system by the economic benefits per household in each time period.

Step 4 - Calculate the Discounted Present Value of the Time Stream of Benefits Over the Planning Horizon

The benefits to each group of affected households in each time period may be added together and discounted to obtain an estimate of the total benefits to the community of the improved water system.

C. Type II Projects (Existing Markets): Benefits to Households
Already Connected to a Piped Distribution System

The supply of water received by households in Group D from the existing piped distribution system is likely to be unreliable. This is because there is typically excess demand for water at the prevailing price, and the water utility must find a way of rationing the available supply. Higher prices are rarely used by water utilities to ration available supplies; this is typically done by low pressure and supply interruptions. Because water systems in need of expansion in developing countries are typically plagued with reliability and distribution problems, households in Group D do not in practice receive the benefits that would be associated with purchasing their current water quantity at the prevailing price. This is because households typically want reliable water supplies. The economic benefits of a system capacity expansion not only include the consumer surplus associated with the increased supply, but also households' willingness to pay for the provision of the existing supply with greater reliability.

The benefits of increased reliability to existing customers are difficult to measure using the c-factor approach because an estimate of the consumer surplus associated with the increased water use cannot capture the benefits households obtain from having their existing water supply available on a reliable basis. A contingent valuation approach is recommended to estimate the benefits of enhanced reliability to Group D households. If the time and resources are not available to carry out a such a contingent valuation study, the analyst can obtain a lower bound estimate of the value of increased reliability by determining how much time and money Group D households are spending to deal with poor reliability (i.e., paying for water storage facilities, backup systems, etc.).

The time profile of benefits to Group D households can be estimated in the same manner as for Group A, B, and C households.

D. Concluding Remarks

In this paper it has been argued that there is a need for both improved procedures and better practice in the estimation of the economic benefits of water supply projects. We have discussed several approaches that can be used to estimate the economic benefits to households of water supply improvements. The selection of the appropriate approach for a given situation will depend on the time and budget constraints of the agency doing the economic analysis. However, in general all of the recommended approaches require at least some data collection at the household level. Household water demand behavior is sufficiently complex, and existing data on household water use are so limited that it is rarely advisable to rely solely on desk studies to estimate project benefits. Primary data collection (including household surveys) is necessary during project preparation and appraisal in order to improve the quality of benefit estimates.

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