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Incorporating demand-side information into water utility operations and planning*

Steven Renzetti

Brock University, Canada

In the past, the efforts of most water utilities to provide potable water flows focused primarily on issues related to the supply of water to meet the needs of water users. The underlying assumption in this approach was that these ‘needs’ were exogenously determined and not sensitive to policy measures available to water utilities. A number of factors, including declining funding from senior levels of government, rising costs of raw water supplies, expanding knowledge regarding the economic features of water demand and rapidly growing levels of water use, have led researchers and utility managers to promote the principle of incorporating demand-side information into utility operations and planning. Another factor supporting this trend is the growing participation of private firms in water supply and the growing interest on the part of public utilities of adopting ‘business models’ of operation (Hargreaves 2001).

Operational areas that have been affected include pricing, forecasting and investment planning. The goal of these efforts is to promote efficient and environmentally sustainable utility operations by balancing supply and demand considerations more equally. As Wegelin-Schuringa (2002: 1) argues, ‘It has been demonstrated in many countries that saving water rather than the development of new sources is often the best “next” source of water, both from an economic and from an environmental point of view.’

The purpose of this chapter is to examine the application of demand-side information to water utility operations such as pricing, forecasting, drought management and capital investment planning (more detailed discussions are found in Baumann *et al.* 1998; Renzetti 2002a). It should be pointed out that the topic of

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demand-side management is seen here as only one of several possible ways in which information regarding water demands can be incorporated into water utility planning and operations. In the next section I address conceptual issues relating to the employment of demand-side information; in Section 1.2 I report on several specific operational areas where water utilities may employ demand-side information.

1.1 Principles

In economic theory, an allocation of productive resources (capital, labour, water, etc.) is said to be efficient if the economy's pattern of production and consumption cannot be changed in such a way that improves the welfare of any individual without lowering the welfare of another. It can be shown (Boadway and Bruce 1986) that this rather general-sounding definition has direct implications for the operations of any specific industry—including those that supply water.

The general definition of economic efficiency implies that each industry's output should be produced at a level where the marginal benefit from the last unit of consumption equals the marginal cost. In a competitive market, this is brought about by fluctuating market prices. In the case of local water supply, this must be brought about through administratively set prices. If this is to be the case, then information regarding the costs of supply and the benefits of consumption is needed. As a result, it is difficult to imagine a water utility achieving an efficient level of output without having collected information regarding its costs and the demands for its output and using these to determine the marginal costs and benefits of differing levels of output.

This principle of comparing costs and benefits extends beyond choosing the efficient level of output. As the specific applications in Section 1.2 demonstrate, a number of aspects of utility operations (including investments, forecasting and rationing) need to follow this dictum if they are to be carried out efficiently. Different applications, however, will require different types of information. In principle, there are a variety of features of water demand that water utilities would need to ascertain prior to implementing the types of applications discussed below.

There are two broad sets of information that water utilities need to collect. The first relates to those factors that influence decision-making regarding the quantity of water consumed. In the case of residential water demands, economic theory predicts that water use is a function of such factors as the price of water, the prices of other goods (e.g. the price of electricity), household income, the stock (and age) of household water-using appliances and climate. The sensitivity of household water use to each of these variables is something that can only be assessed empirically by applying econometric estimation techniques on locally collected data (Renzetti 2002a). In the case of commercial and industrial water demand, economic theory predicts that non-residential water use is a function of the price of water, the prices of other inputs, the uses to which water is put (e.g. in cooling, processing and steam production) and the level of production. As in the case of residential water demands, the sensitivity of commercial and industrial water use to each of these factors is something that must be determined empirically (Renzetti 2002b).

The second type of information relates to users' valuation of various features of water supply. Although the average person's valuation of the small amount of water drunk each day is obviously quite high (as evidenced by the recent rapid increase in sales of bottled water—often at 500 times the cost of tap water), much less is known about households' valuation of less important uses of water such as for showering, watering the lawn and garden and for washing clothes. Furthermore, relatively little is known about the role played by socioeconomic factors such as income and family size in determining these values. The same can be said for industrial users of water. In some cases, the use of water (such as in the production of some foodstuffs) is of critical importance and thus highly valued. In other cases, where the use of water is not critical (perhaps because of the presence of substitutes such as alternative means of cooling the intermediate inputs), firms' valuation of water can be expected to be much lower.

1.2 Applications

There are a number of facets of water utility operations for which the efficiency can be improved through the incorporation of demand-side information. As indicated in Section 1.1, in order to achieve an efficient level of water use (and the related efficient level of investment) it is necessary to balance the marginal costs and benefits of consumption, where the benefits can be estimated only by determining households' (and other consumer groups') valuation of water use. In this section I review these areas and, where possible, present empirical evidence of the reform of water utility operations.

1.2.1 Use of efficient pricing

From the point of view of the allocation of scarce water resources, one of the most important facets of water utility operations is pricing. This is because changing prices provide a signal to consumers and suppliers of the changing costs of consumption. Increasing water prices encourage consumers to conserve and search for alternatives; such increases also act as an incentive for utilities to search out previously unattractive supply options. This may be done by reducing system losses, investing in more efficient pumps or water meters or leasing water rights.

Historically, however, the primary goals of price setting were to recover sufficient revenues to cover costs and to assign common capital costs across user groups in an equitable fashion (AWWA 1991). In keeping with the view that water demands are exogenously determined, the potential role of water prices to signal the opportunity cost of consumption and, thus, allocate water to its highest valued uses has not been emphasised in the industry. This perspective has had a number of negative consequences. Most importantly, water prices have failed to reflect the marginal cost of supply and typically have been invariant in relation to distance from source, time of use or season (Renzetti 1999). The implication of these inefficient prices is that consumption has grown past its socially optimal level and all components of water supply and waste-water networks have correspondingly expanded to accommodate this.

There is a growing body of empirical evidence that moving to efficient water pricing will provide a number of benefits to water utilities and often will raise social welfare (Hall 1996; Renzetti 1999; Saleth and Dinar 1997). An important feature of these prices is that they are designed to reflect the marginal cost of water supply and also to ensure that demand equals supply. As such, they depend crucially on the nature of water demand and cannot be calculated without fairly detailed information regarding the water demands of all customer groups. Another characteristic of efficient pricing is that prices can be tailored to reflect local cost and demand conditions. Efficient non-linear pricing (i.e. price schedules where the marginal price rises or falls with the level of consumption) can be designed to take account of observed variations in demand elasticities across user groups, in different time-periods or over different levels of consumption. More sophisticated price schedules, however, require greater information regarding the nature of water demand and the distribution of socioeconomic characteristics across households (Brown and Sibley 1986).

Despite these informational challenges, a number of studies demonstrate the feasibility and benefits of moving to efficient water pricing. In cities as diverse as Vancouver, Los Angeles, Manila and Hyderabad researchers have demonstrated that implementation of efficient pricing increases social welfare while encouraging water conservation (Hall 1996; Munasinghe 1992; Renzetti 1992; Saleth and Dinar 1997). For example, in earlier work (Renzetti 1992) I looked at the welfare gains from reforming water prices for the Greater Vancouver Water District and estimated the potential improvements to be approximately 4% of households' welfare (as measured by aggregate consumer surplus). It is worthwhile pointing out that these welfare gains are net of the costs of introducing universal residential water metering in Vancouver.

1.2.2 Management of demand

One area where water utilities have demonstrated an interest in applying demand-side information is in the management of household and other users' water demands (Opitz and Dziegielewski 1998). Although there remains some debate regarding the definition and assessment of demand-side management (DSM) policies (Dziegielewski 1999) it is clear that many utilities, when faced with rising use of water and/or inadequate levels of service capacity, are examining the efficacy of alternative measures to encourage water conservation (a partial list of potential measures is found in Box 1.1).

Given the variety of price-related and non-price-related measures to encourage water conservation, an important area of research has been to assess the relative efficacy of alternative DSM policies. Renwick and her co-authors have recently examined the experience of Californian water utilities that have employed a variety

Water utilities have employed a variety of policies and measures to encourage water conservation. A partial list of options includes the following:

- Education and advertising campaigns
- Revision of plumbing, building and landscaping codes
- Pricing instruments (and installation of metering, if necessary), such as increasing block-rate structures, seasonal pricing, charges for excess use and zonal pricing
- Other financial incentives, such as rebates, subsidised retrofits and water audits
- Leak detection, the reduction of system pressures and the removal of illegal connections
- Rationing, such as limiting the time of use or the quantity used (e.g. through banning the use of water outdoors, such as for watering gardens, or through the imposition of alternate-day rules)
- Moral persuasion (i.e. through calls for voluntary reductions)
- Encouragement and training regarding recycling and/or recirculation of water
- Demand modelling and estimation

BOX 1.1 Alternative demand-side management policies and instruments

Sources: Guy and Marvin 1996; Opitz and Dziegielewski 1998; Wegelin-Schuringa 2002

of methods ranging from requests for voluntary compliance, price increases and penalties for overusing water as methods of coping with the drought that hit that state in the 1990s (Renwick and Archibald 1998; Renwick and Green 2000). Renwick and colleagues' statistical models of water demand and household retrofit decisions demonstrate that price and non-price measures curb demand. Non-price measures vary in their effectiveness, with policies that mandate reduced use of water being more effective than voluntary measures. Renwick and Green (2000: 51) conclude that,

> In general, relatively moderate (5–15%) reductions in aggregate demand can be achieved through modest price increases and 'voluntary' alternative DSM policy instruments such as public information campaigns. However, to achieve larger reductions in demand (greater than 15%), policy-makers will likely need to consider relatively large price increases, more stringent mandatory policy instruments (such as use restrictions), or a package of policy instruments.

In his study of water conservation efforts in low-income countries, Brooks (1997: 4) echoes this conclusion, asserting,

> Although regulations have a bad name, they are often both appropriate and efficient for managing water demand. Exhortation is also more effective than generally believed, particularly in times of drought. The range of options is wide enough to preclude generalisation, but one can say that they should be chosen to support, and if possible reinforce, the effects of market-based measures.

1.2.3 Investment decisions and forecasting

The traditional approach to water utility investment planning has been to schedule major infrastructure extensions and improvements according to expected growth in water use. The most important feature about the growth in water use has been that utilities assumed it to be outside their sphere of influence. As a result, water utilities perceived a need to provide infrastructure to support water use wherever and whenever it occurred. As described in Section 1.2.1, the lack of efficient pricing (such as peak-load or zonal pricing) reinforced this investment strategy by failing to promote water conservation.

An alternative approach to infrastructure planning balances households' valuation of infrastructure with the costs of that infrastructure. Specifically, additions to a water utility's infrastructure are scheduled so as to maximise the present value of the stream of discounted future net benefits deriving from those investments. Net benefits in this context are measured as the difference between benefits (measured by consumers' willingness to pay for increments to capacity, reliability or water quality) and costs. A significant part of the scheduling of infrastructure projects involves forecasting future water demand (and, thus, the benefits from additional capacity). Furthermore, sophisticated forecasts of water demand can incorporate the effects of policies such as pricing, development charges and plumbing standards that are available to municipal governments (Billings and Jones 1996).

The interaction between pricing and investment planning is especially important. In an earlier publication (Renzetti 1992), for example, I demonstrated that one of the most important benefits of introducing prices that are based on estimates of customer demand is the utility's ability to delay costly expansions to its delivery capacity. Another emerging application of information regarding households' valuation of water supply and waste-water treatment infrastructure is found in a number of low-income countries. In areas such as rural Africa and Asia that are often plagued by inadequate infrastructure the ability to demonstrate households' willingness to pay for improved access to potable water supplies plays an important part in signalling the financial viability of infrastructure investments (WBWRT 1993). Asthana (1997), for example, conducted a contingent valuation study of rural Indian households in which the female head must often carry water from distant standpipes and communal wells. Asthana found that these households place a high value on improved provision of water supplies, stating that, 'on the average, the amount that they are willing to pay for saving in time is equal to half the wage for unskilled rural labour' (1997: 147).

1.2.4 Evaluation of performance

In the private sector, a key measure of success is customer satisfaction. The public sector, however, has been much slower to measure customer satisfaction or to incorporate these measures into the evaluation of its performance. An interesting exception to this general rule can be found in the use of consumer satisfaction ratings by England's Office of Water (OFWAT). Since the time that water and sewerage utilities in England and Wales were privatised OFWAT established levels of performances (e.g. regarding system reliability) and has commissioned surveys into consumer satisfaction and willingness to pay for system improvements (Reid *et al.* 2002).

The discussion in Section 1.2.2 indicates that there is a growing body of research and acceptance among water utilities regarding the benefits of incorporating demand-side information into pricing, investment decision-making and performance evaluation. This list, however, does not exhaust the possibilities for incorporating demand-side information. There are at least two other ways in which demand-side information may be utilised. These approaches, however, have only recently been suggested and, thus, a significant amount of research is needed before they can be implemented. They are included, however, to give the reader an idea of the full range of possibilities for employing demand-side information to enhance water utility operations.

Reliability

A crucial feature of the design and operations of any water supplier is its targeted level of reliability. It is well understood that demands (which are in some cases closely dependent on uncertain factors such as climate conditions) can at certain periods threaten to exceed system capacity and that unexpected breakages can inhibit supply reliability. As a result, no system is 100% reliable. In addition, increases to system reliability can often be very expensive. Traditionally, engineers have designed water utilities to meet targets of arbitrarily set reliability (such as meeting peak demands 95% of the time). However, in choosing to meet an arbitrarily defined target, designers rarely attempt to determine whether these targets are the ones desired by consumers and taxpayers. Once again, the absence of demand-side information means that there can be no assurance that the efficient level of reliability (i.e. where the marginal costs and benefits of an incremental change in the level of reliability are equated) is achieved.

An alternative approach to the decision regarding reliability is to balance the costs and benefits of differing levels of reliability. This approach recognises that households and other water users value increased reliability but that the investments needed to achieve this have their own opportunity costs. Those funds can be invested in improved roads, schools and hospitals—all things that households also value. In order to balance these benefits and costs, however, information regarding households' (and other customers') valuation of differing levels of reliability must be ascertained. For example, Howe and Griffin Smith (1993) conducted a contingent valuation survey of households and found that residential users of water in the state of Colorado were willing to pay approximately US$60 annually beyond their current water bills in order to halve the likelihood of a major system failure. Once aggregated, these willingness-to-pay estimates could be compared with the costs of achieving this increase in reliability in order to determine whether the investment was merited.

Rationing

The same type of argument as found in the above section can be made regarding the methods used by water utilities to ration water use in times of drought when water demands threaten to exceed available capacity. Traditionally, water utilities have employed some form of administrative rationing such as allowing even-numbered houses to use water for outdoor purposes only on even-numbered days, or limiting outdoor water use to specific periods of the day. These methods of rationing consumption are relatively straightforward to design, implement and enforce but they do nothing to guarantee that the scarce water resource is allocated to its highest-valued uses. As a result, they will typically result in an inefficient allocation of water.

An alternative approach that employs households' valuation of access to the supply network may be feasible and result in a more efficient allocation of scarce water. Specifically, it may be possible to design a rationing scheme that relies more heavily (but not exclusively) on users' valuation of access to the network. For example, at the beginning of each year, households could signal their valuation of continued access in times of rationing by purchasing differing levels of service reliability. Higher levels of service reliability would cost more. As water supply must be maintained for indoor and fire-protection needs, this scheme would be applicable only to outdoor use of water (and, possibly, some types of industrial use of water). Once households have signalled their respective willingness to pay for reliability, a ranking of differing households could be established. The higher a household has paid for access, the lower the likelihood of it having its access interrupted or curtailed. In times of rationing, such a scheme would ensure that only the households with the highest valuation of water would be using the scarce water resource as households with the lowest valuation would be the first to be excluded from use. Such a price-based rationing scheme is already in place for industrial consumers of electricity where higher levels of reliability entail higher prices (Brown and Sibley 1986).

1.2.5 Summary

This list of applications is suggestive of the range of activities that could be reformed through a greater reliance on demand-side information. It is valuable to note that there are, in all probability, synergies between the applications. For example, if a utility were to collect and analyse data on the factors shaping household and commercial water demands with the aim of reforming its pricing practices, then the utility could also use the same data and estimated demand models for enhanced forecasting and investment planning. Similarly, the estimated consumers' valuation of alternative levels of reliability could be used for enhanced evaluation of performance.

1.3 Conclusions

In this chapter I have considered the application of demand-side information to a number of facets of water utility planning and operations. For many utilities, the idea of gathering and analysing data on features such as consumer sensitivity to price change and consumer willingness to pay for infrastructure improvements is unfamiliar. Nonetheless, many other utilities (including those in Los Angeles, Seattle and Toronto) have experimented with price and non-price measures to conserve water use and have used information regarding water demands to assess the costs and benefits of major infrastructure projects.

What is clear is that economic theory and a growing body of empirical evidence support the redirection of the attention of water utilities towards a more balanced approach that incorporates benefit and cost information in their planning and operations. It should be remembered, of course, that there will be costs associated with moving in the directions indicated here. These include the costs of data collection and analysis, the costs of hiring new staff and of retraining existing staff and the costs of public consultation and education as well as a potential increase in the degree of uncertainty faced by the utility. The main new source of uncertainty may stem from the linking of prices to demand conditions, thereby making revenue more uncertain. Nonetheless, the available empirical evidence indicates that, even accounting for these costs, the reorientation of the focus of water utility operations in the direction of a greater reliance on demand-side information will bring benefits to the utility and to its customers.

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