NRRI 94-18

REVENUE EFFECTS OF WATER CONSERVATION AND CONSERVATION PRICING: ISSUES AND PRACTICES

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September 1994

This report was prepared by The National Regulatory Research Institute (NRRI) with funding provided by participating member commissions of the National Association of Regulatory Utility Commissioners (NARUC). The views and opinions of the authors do not necessarily state or reflect the views, opinions, or policies of the NRRI, the NARUC, or NARUC member commissions.

CHAPTER 3

WATER CONSERVATION PRICING

Conservation-oriented rate structures increasingly are advocated as a necessary part of long-term water planning and management strategies. In fact, conservation pricing can be considered a necessary, but not always sufficient, part of promoting wise use of water resources. It is necessary because an appropriate pricing signal is critical for guiding water consumers in their consumption decisions and water suppliers in their supply decisions. Pricing can be insufficient, however, to the extent that water consumers and suppliers may lack adequate and reliable information for interpreting prices.

The prevailing economic view is that the price of utility services, including water service, should reflect true costs.[1] Though it may seem simple enough, the alignment of utility costs and prices still remains more art than science.[2] Conservation-oriented pricing makes these points especially clear. The use of prices to manage demand is not easily divorced from the utility's ability to meet revenue requirements. A poorly designed rate structure can jeopardize the financial health of the utility and cause ratepayers to suffer the consequences. A well-designed rate structure can help a utility manage its supplies more efficiently, encourage consumers to make wise choices, and have positive environmental and social effects as well.

The demand for water is not perfectly price-inelastic; that is, water usage by customers is inversely related to the real price charged for water service. Thus, rate increases can be a singularly effective method of conservation. However, it is important to recognize that if water rate increases lag behind inflation rates, there can be an implicit incentive for customers

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[1] See D. C. Gibbons, *The Economic Value of Water* (Washington, DC: Resources for the Future, 1986).

[2] Janice A. Beecher and Patrick C. Mann, *Cost Allocation and Rate Design for Water Utilities* (Columbus, OH: The National Regulatory Research Institute, 1990).

to increase water usage. In conservation pricing, the real price of water (which screens out inflationary effects) is more important than the nominal price of water.

This chapter considers conservation-oriented pricing for the water sector. Some basic conservation-oriented rate structures and their advantages and disadvantages are briefly reviewed. Because of the importance of price elasticity of demand in predicting the impact of a change in price on utility sales and revenues, considerable attention is paid to the ever-evolving literature in this area and its implications for water utility ratemaking.

Pricing for Efficiency

A planning perspective recognizes that pricing is more than simply the means of meeting revenue requirements. It sends a signal that in turn affects demand that in turn affects the design of the water system. A planning framework allows the consideration of nontraditional approaches, not only marginal-cost analysis but variable-rate structures (such as seasonal rates and increasing-block rates) that can be used to implement it. Planning could force a more thorough evaluation of the incremental costs associated with adding capacity.

Efficiency is an untapped resource in the water sector partly because of distorted prices. Water resource economists have long attributed many of the distributional problems in the water sector to the lack of cost-based price signals. Regulatory economists have pressed for efficiency-oriented pricing in the private sector.[3] The criteria for efficiency pricing in the regulated water sector have been well-documented.[4] For public-sector water utilities, many analysts have emphasized the need to move toward rates that recover the true cost of service

[3] Patrick C. Mann, *Water Service: Regulation and Rate Reform* (Columbus, OH: The National Regulatory Research Institute, 1981). See also, Beecher and Mann, *Cost Allocation.*

[4] Steven H. Hanke and John T. Wenders, "Costing and Pricing for Old and New Customers," *Public Utilities Fortnightly* (April 29, 1982): 46.

without underpricing (requiring a transfer from the governing body), overpricing (providing a transfer to the governing body), or subsidizing some customers at the expense of others.[5]

Efficient pricing is based on marginal-cost pricing theory. Marginal cost is the additional cost of producing or selling the next additional unit. The marginal cost of water service is the cost incurred in providing the additional water service. In practical terms, the two essential components of marginal costs are, first, the change in operating costs caused by changing the utilization rate for existing capacity, and second, the cost of expanding capacity, including the operating costs associated with the increased capacity. If the water utility is operating below capacity, marginal cost involves the incremental operating cost of producing more product units within the existing system capacity. In contrast, if a capacity increment is required, marginal cost involves the new capacity costs and the new operating costs. Calculating marginal costs involves projecting capacity and operating costs for a specified time span given a particular demand forecast.

Avoided cost is a concept that emerged in part from federal policies designed to require electric utilities to purchase electricity from independent (that is, nonutility) power producers (or qualified cogenerators and small-power providers). The rate used is based on the incremental energy and possibly capacity costs the utility would have incurred if it would have generated the additional power itself or purchased it from another source. While the use of avoided cost in the water sector is not identical to its use in the energy sector, it still has relevance. The marginal or incremental cost of conservation, for example, can be compared to the avoided cost of providing one less unit of water to consumers. This comparison can be useful in identifying least-cost planning alternatives.

Economic theory recognizes that water demand is malleable and can be manipulated by price to some degree. Water supply, even though a monopoly, is not exempt from the economic forces governing supply and demand. Academic economists, in particular, have argued that policymakers (including state public utility commissioners) should aim toward "competitive pricing" for public and private water suppliers and that water prices should be

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[5] See J. Goldstein, "Full-Cost Water Pricing," *American Water Works Association Journal* 78, no. 2 (1986): 52-61.

used to "damp down demand to the available supply," as in the larger market-oriented economy.[6] Contemporary lessons from Europe, according to one academician, indicate how pricing is a far more "virtuous" system than bureaucracy for processing economic information.[7] Although somewhat rhetorical, the underlying argument for the importance of pricing to achieve conservation goals is essentially sound.

In applied regulatory economics, considerable effort is devoted to the intricate and circular relationship among water system capacity, costs, prices, and demand. For conservation purposes, the emphasis narrows to demand and its response to price. Demand for indoor water uses is less sensitive to changes in price than demand for other outdoor uses. Only for basic drinking water needs (for survival) is demand virtually unresponsive to price. A price increase when the price is very low to begin with will not necessarily affect demand to a large degree. At higher prices, however, it can be hypothesized that demand is more price responsive. Another issue is the potential for a cultural and generational effect on water-consumptions habits caused by the increase in environmental awareness by water customers. Today's consumers are exposed to more information and options regarding their resource consumption, in part due to conservation programs advanced by energy utilities but also through community recycling and other efforts that affect consumer consciousness. Economic pressures can induce some consumers (especially large-volume customers) to seek out ways to reduce their utility costs. These motivated consumers are more likely to respond to changes in price. Thus pricing is an essential but not necessarily a sufficient mechanism for manipulating consumption (as discussed in the previous chapter). As seen later in this chapter, a great deal of effort has been devoted to the study of the price variable in econometric studies of water demand.

Conceptually, price-induced water conservation involves a reduction in the quantity of water demanded (that is, a movement along a given demand curve). Other structural changes, such as changes in consumer preferences or income levels, can result in shifting the demand

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[6] Laurence S. Seidman, *Recommended Water Conservation Policies,* a paper prepared for the Water Resources Agency for New Castle County, Delaware (July 12, 1991), 1-2.

[7] Ibid.

curve for water. Economists stress important theoretical differences between these structural and behavioral phenomena and their effects on the equilibrium between supply and demand. From a practical standpoint, all types of usage reduction from conservation, if not anticipated in the determination and allocation of revenue requirements, can lead to a revenue shortfall for water utilities (that is, a disequilibrium). In rate regulation, with its focus on the generation of revenues to match revenue requirements, it is probably not of substantive importance whether the usage reduction involves a decrease in *quantity demanded* or instead involves a decrease in *demand.*

The Conservation-Pricing Debate

The well-established theory behind efficiency pricing is not debated here, in favor of turning attention toward more pragmatic issues of conservation pricing, that is, pricing designed explicitly for demand management and demand reduction purposes. Pricing has been recognized as a tool for managing demand during periods of drought.[8] However, it has not always been recognized as a method for accomplishing long-term demand management. Agreement at the theoretical level sometimes breaks down during actual implementation of a pricing structure. The general advantages and disadvantages of conservation pricing are summarized in table 3-1. Some of the more compelling arguments are discussed below.

The Argument in Favor of Conservation Pricing

Conservation and conservation pricing have been well-recognized as having positively operational effects on utilities in terms of postponing or deferring capital expansion for wastewater and water services, decreasing operating expenses for pumping and chemical treatment, and reducing water purchases from wholesale suppliers. Conservationist,

[8] S. F. Mack and B. Ferguson, "Water Rates and Revenue Impacts of Severe Drought Response, City of Santa Barbara, 1990-1993," in *Proceedings of Conserv93* (Denver, CO: American Water Works Association, 1993), 673-680.

TABLE 3-1
ADVANTAGES AND DISADVANTAGES OF
CONSERVATION-ORIENTED RATE STRUCTURES

Advantages of Conservation-Oriented Rate Structures

- Metering and cost-based pricing send an appropriate economic signal to guide consumption decisions and generally are regarded as equitable.
- The cost of developing new supplies can be attached to existing use.
- Expansion of water systems into difficult-to-serve areas can be discouraged.
- The useful life of existing capacity can be extended and the need for new capacity can be postponed.
- Diseconomies in distribution can be offset by overall operational economies.
- Managing demand through price can be essential during water-supply emergencies, such as extreme cases of drought.
- Cost-based pricing enhances water-system financial viability.

Disadvantages of Conservation-Oriented Rate Structures

- Manipulating demand through prices is perceived to cause net revenue instability.
- Some forms (such as increasing-block rates and sliding-scale rates) can increase the threat of bypass by large-volume customers, which can lead in turn to the problems of underutilized capacity or stranded investment.
- A decrease in average demand can occur without a concurrent decrease in peak demand, which only exacerbates the utility's problem of covering fixed costs.
- Complex structures can require more advanced metering capability and/or more sophisticated cost-tracking methodologies, which can be costly.
- Apparent inconsistency with conventional cost-of-service and consumer-choice principles can be a problem.
- Some alternatives (such as penalties) can be perceived as punitive and may be appropriate only for extreme circumstances.
- Pricing structures can be incompatible with the economic development goals of the community served by the water system.

Source: Authors' construct.

environmentalist, and natural resource perspectives tend to regard all varieties of conservation (that is, any reduction in total or per capita water use) as highly beneficial.

The interest in rate structures that promote efficiency and conservation is related to several fundamental criticisms of conventional ratemaking for water utilities. Water pricing generally has ignored the circularity that exists in the relationship among capacity, cost, price, and demand. That is, changes in price lead to changes in quantity demanded and so on. The consequence was that demand was largely taken as a given and utility managers sought to continually add capacity to meet that demand, plus some excess capacity for meeting anticipated demand growth. In other words, the potential to manage utility loads through pricing (along with other tactics) was not often considered. Other utility sectors have long recognized load management as a short-term operational strategy and a long-term planning strategy.

Conventional pricing strategies also have tended to ignore variations in cost associated with variations in demand. The result is a potential subsidy of peak users by off-peak users. The variety of peak-load pricing models is substantial. In telecommunications, for example, time-of-day pricing is frequently used. For the water sector, seasonal pricing is more appropriate for meeting efficiency goals. Seasonal rates recognize that the peak user is the cause of much of required system capacity. For water utilities, seasonal rates can improve capacity utilization rates while constraining capacity requirements. Perhaps most importantly, seasonal rates convey efficient or conservation-oriented price signals to consumers. In brief, the anticipated effects of seasonal rates include load shifting, capacity savings, and possibly reduced consumer bills.

From a more pragmatic perspective, metering and conservation rate structures simply save water. Pricing policies and other conservation-oriented policies in Tucson, Arizona probably have been studied more than those for any other city.[9] Over the years, Tucson water managers have implemented and modified a variety of conservation-oriented rate

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[9] William E. Martin, Helen M. Ingram, Nancy K. Laney, and Adrian H. Griffin, *Saving Water in a Desert City* (Washington, DC: Resources for the Future, 1984).

structures, providing a wealth of information and data on water savings. Most recently, the rate structure has been simplified to improve equity and consumer acceptance.[10]

A study of increasing-block rates in Tucson estimated weather-normalized water savings of 55 million cubic feet in 1983, 100 million cubic feet in 1984, 150 million cubic feet in 1985, and 130 million cubic feet in 1986.[11] These water savings translate to annual water-use requirements for 3,500 to 9,400 single-family customers, which constitutes 5 to 8 percent of the total customer class requirement. Furthermore, the proportion of residential water use dropped from 60 percent of total system use in 1978 to less than 53 percent in 1986.[12] The author of this particular study concluded that single family residential customers are price sensitive and that increasing-block rates can be an effective demand management tool when used along with other conservation methods. Of course, care should be taken to not overgeneralize from the experiences of this desert city. However, the effect of pricing on water conservation in Tucson and elsewhere has been effectively demonstrated.

The Argument Against Conservation Pricing

Despite the known benefits of conservation pricing, its actual implementation can be problematic. An economic regulatory perspective recognizes that conservation pricing can have mixed effects that must be anticipated and managed for the benefit of both the utility and its customers.

Pricing is similar to other strategies associated with conservation in terms of having both advantages and disadvantages associated with its use.[13] In particular, there exists a

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[10] L. A. Peart and K. D. Warner, "Tucson's Rate Structure Changes Designed to Strengthen Conservation Pricing Incentives," in *Proceedings of Conserv93* (Denver, CO: American Water Works Association, 1993), 655-671.

[11] Richard W. Cuthbert, "Effectiveness of Conservation-Oriented Water Rates in Tucson," *American Water Works Association Journal* 81, no. 3 (March 1989): 65-73.

[12] Industrial use also declined during the period, while commercial and multifamily use (to which increasing-block rates were not applied) increased substantially.

[13] William O. Maddaus, *Water Conservation* (Denver, CO: American Water Works Association), 1987.

tradeoff between revenue stability in the short-term and improved economic efficiency in the long-term. Revenue instability is the most frequently cited problem with various forms of conservation rates. Since most water rates are tied to the volume of water consumed and since conservation causes a reduction in use, conservation will cause utilities to experience reduced revenues and an unstable cash flow. Thus, the shift toward conservation rates increases the variability of future revenue flows. Another implication of revenue instability is the potential for increased cost of capital for the utility. In addition, delaying supply projects may inflate construction costs. These adverse financial effects could cause utilities to lose public support for future supply projects.

Conservation ratemaking can raise several efficiency issues, including: (1) the lag between rate implementation and actual conservation effects; (2) the accuracy of predicting the magnitude of short-term and long-term reductions in usage, revenue, operating cost, and capital costs; (3) the effectiveness of conservation rates over time; and (4) the administrative costs of the conservation rate program relative to benefits.[14] In addition, the actual effect of seasonal and other rates on load shifting (and therefore on capital and operating requirements) will be uncertain, because consumer responsiveness to prices in today's economic environment remains uncertain for many water utilities.

A key concern with regard to seasonal rates is the potential to reduce average but not peak or maximum demands. Remaining "needle peaks" leave considerable capacity unused and capital costs must be spread over a smaller amount of average usage. For utilities that have plentiful capacity, some forms of *short-term* conservation can be regarded as inefficient because of existing system-cost economies. It seems inappropriate to ask customers to conserve when supply capacity is readily available. Conservation in this instance can result in less usage at a higher cost to consumers, which clearly does not improve their welfare.

Despite their appeal to environmentalists, some conservation rates (such as increasing-block rates), may not accurately reflect the cost of water service. The true costs of water

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[14] Gary C. Woodard, "A Summary of Research on Municipal Water Demand and Conservation Methodologies," *Water Pricing and Water Demand* (Phoenix, AZ: Arizona Corporation Commission Utilities Division, August 1986), 19-47.

service, depend in part on the cost of providing additional units of water, the cost of providing additional units of water at system peak and off-peak times, and the cost associated with providing service to additional customers.[15] Large-volume users who are price sensitive (that is, their demand is more price sensitive) might expect a volume discount through decreasing-block rates. Conservation rates (whether or not cost-based) may induce bypass by large-volume users who can use self-supplied water. Even though this could result in long-term system and allocational efficiencies, the short-term revenue effect can be devastating for the utility and the remaining customers who must cover the revenue requirement.

Some water rate analysts have focused specifically on the prudence of eliminating decreasing-block rates, even in the face of pressure to conserve water resources. John Guastella, for example, raises several pertinent questions: (1) Is the demise of decreasing-block rates cost-justified? (2) Does the elimination of these rates really promote conservation? (3) Are better conservation-oriented rates structures available? (4) Do the alternatives simply provide a subsidy from high-volume to low-volume users? and (5) Are regulators adequately considering cost-of-service and revenue-requirement issues when eliminating decreasing block rates.[16] One particularly troublesome result of the transition from decreasing-block to uniform rates is that a *reduction* in rates for low-volume usage (accompanied by a rate increase for high-volume usage) appears to provide a discount for basic water service. This price signal can induce consumption by low-volume users, which runs contrary to conservation goals.[17]

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[15] Ibid.

[16] John F. Guastella, "Rate Design Issues: Single Tariff Pricing and Conservation Rates," *Biennial Regulatory Information Conference* (Columbus, OH: The National Regulatory Research Institute, 1994). Draft dated March 3, 1994. See also, Thomas R. Stack, "Potential Consequences of Abandoning Cost-Based Declining-Block Rates," in *Proceedings of the Biennial Regulatory Information Conference* (Columbus, OH: The National Regulatory Research Institute, 1992).

[17] Assuming that the tail blocks cover peak demand, however, overall efficiency may justify the appearance of a rate discount in the initial blocks. Also, reducing the rate for the initial blocks may not be cost-justified or necessary in a phased approach.

Finally, more efficient pricing of water service can lead to substantially higher water bills. Among other things, this presents an affordability problem for low-income customers who may have to make significant sacrifices to maintain essential utility services. Thus, conservation pricing can be met with resistance by high-use and low-use customers alike. Resistance to price increases or changes in the pricing structure often is manifested in political turmoil for members of ratemaking bodies (including both state commissions and local governing boards).

The Counterpoint

Concerns about conservation pricing are legitimate and cannot be dismissed lightly. Water utility managers are rightly concerned about the actual effectiveness of conservation rates and the financial effects of reduced water usage. Unless they are convinced that the projected long-term cost savings are realistic, the reluctance to implement conservation rates will persist.[18] The fact that implementing a conservation-oriented rate structure can be complicated, and even political in nature, is not really disputed.

However, a persuasive counterpoint argument is taking shape. Some economists have argued that the implementation issues associated with moving from average-cost to marginal-cost pricing (including price, revenue, and earnings volatility) can be addressed and that these perceived barriers are no excuse for disregarding marginal-cost and seasonal pricing for water utilities.[19] In particular, it is unnecessary to estimate marginal costs with precision in order to design more efficient water rates. Put one way, "approximately right" is better than "precisely wrong."[20] Water systems can move toward conservation-oriented rates (including

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[18] William O. Maddaus, "Integrating Water Conservation into Total Water Management," *Journal American Water Works Association* 82 (May 1990): 12-14.

[19] Patrick C. Mann and Donald C. Schlenger, "Marginal Cost and Seasonal Pricing of Water Service," *American Water Works Association Journal* 74, no. 1 (1982): 6-11.

[20] This phrase is borrowed from the growing literature on incentive regulation for public utilities. Kurt A. Strasser and Mark F. Kohler, *Regulating Utilities with Management Incentives: A Strategy for Improved Performances* (New York: Quorum Books, 1989), 171.

increasing-block rates), and reduce water usage without jeopardizing revenues.[21] According to some financial analysts, rate structures used to smooth load shapes can actually enhance revenue stability.[22] In other words, managing peak demand through appropriate tail-block pricing can be very useful. Water utility planners can use computer models to evaluate conservation rate structures and their effects on revenues and other areas, as depicted in figure 3-1.[23] Today, the revenue effects of conservation and conservation pricing can be anticipated and estimated, so that attention can be turned to strategies for managing these effects.[24]

With time, even some of the political complexities of conservation pricing can be overcome.[25] From a strictly economic standpoint, conservation rates do not require public approval since once these rates are implemented they will affect water usage regardless of the consequences that could befall politicians and policymakers. That is, irrespective of their popularity (or unpopularity) conservation rates will induce consumers to reduce water consumption by some amount. Cost savings should help build public support for conservation programs, but utilities might have to work hard to assure this outcome. Cost-based conservation rates that promote economic efficiency will be easier for many constituencies to accept than rate structures that appear to be designed for political reasons (such as when rates are kept artificially high or low for a particular class of customers). For many water utilities,

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[21] Jeffrey L. Jordan, "Rates: Consider Conservation Water Pricing," *Opflow* (American Water Works Association) 20, no. 4 (April 1994): 1, 4.

[22] Edward J. Amatetti, "Managing the Financial Condition of a Utility," *American Water Works Association Journal* 86, no. 4 (April 1994).

[23] C. J. Price-Emerson, et al., "Water Conservation Promoting Rate Structure Computer Model," in *Proceedings of Conserv93* (Denver, CO: American Water Works Association, 1993), 1239-82.

[24] Thomas W. Chesnutt, Anil Bamezai, Casey McSpadden, John Christianson, and W. Michael Hanemann, *Revenue Instability Induced by Conservation Rate Structures: An Empirical Investigation of Coping Strategies* (Denver, CO: American Water Works Association Research Foundation, 1994).

[25] Martin, et al., *Saving Water in a Desert City.*

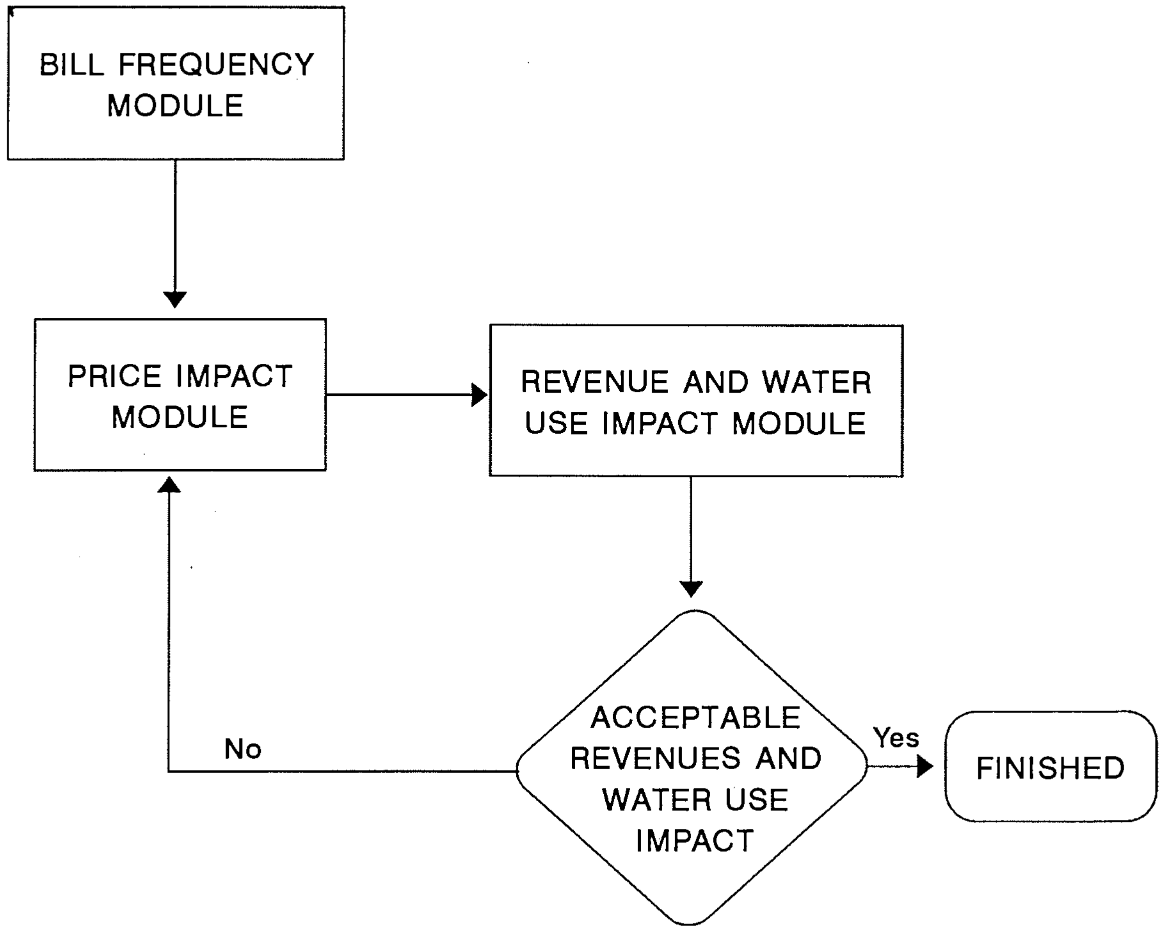

Fig. 3-1. Computer model design for conservation-promoting rate strucctures as depicted in C.J. Price-Emerson, et al., "Water Conservation Promoting Rate Structure Computer Model," in *Proceedings of Conserv93* (Denver, CO: American Water Works Association, 1993), 1242.

a phased approach can help mitigate against the adverse economic and political effects associated with changing the rate structure.

Certainly, utility managers and regulators must consider potential tradeoffs before implementing dramatic changes in the rate structure to achieve conservation or demand management goals. It also is appropriate to consider regulatory and ratemaking mechanisms to offset adverse effects when conservation pricing is mandated.

.Conservation-Oriented Rate Structures

Entire technical conferences have been devoted to the design of rate structures to promote conservation.[26] Most involve economists well-versed in the efficiency paradigm. Water pricing based on marginal costs, in comparison to alternative rate forms, has been advocated as the correct way to promote conservation.[27] The basic steps for designing a water conservation rate structure appear in table 3-2. By following the steps, the effects of a change in price on utility revenues can be estimated and evaluated.

Several criteria can be used to judge whether a rate structure is conservation oriented: (1) the structural form of the rate; (2) the proportion of costs recovered through fixed versus commodity charges; (3) the effective communication of the pricing signal through customer billing; and, (4) for public-sector utilities, the extent to which the cost of utility service is covered through user fees (that is, rates) or other sources of revenues (such as taxes or general fund transfers).[28] The importance of these factors can be weighted according to

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[26] M. Bloome, *Rate Structures to Promote Conservation: Proceedings of a Conference Organized by the Delaware River Basin Commission and the New York City Water Board.* West Trenton, NJ: Delaware River Basin Commission, 1990; and Arizona Corporation Commission, *Water Pricing and Water Demand* (Phoenix, AZ: Arizona Corporation Commission Utilities Division, 1986). See also, American Water Works Association, et al., in *Proceedings of Conserv93* (Denver, CO: American Water Works Association, 1993).

[27] B. C. Lippiatt and S. F. Weber, "Water Rates and Residential Water Conservation," *American Water Works Association Journal* 74, no. 6 (June 1982): 279-281.

[28] Marvin Winer, et al., "Definition of Water Conservation Promoting Rates," in *Proceedings of Conserv93* (Denver, CO: American Water Works Association, 1993).

TABLE 3-2
STEPS IN DESIGNING A RATE STRUCTURE AND EVALUATING REVENUE EFFECTS

Basic Steps	Basic Considerations
Express a percentage demand reduction goal for the water system	Water demand goal / Current water demand
Estimate the expected reduction in demand based on the price elasticity of demand for the service territory, by customer class if appropriate	Factors to consider and their relationship to elasticity: prices (+), consumer income (-), persons per household (-), rainfall (-), temperate climates (-)
Determine the percentage change in price needed to achieve demand reduction goals, by customer class if appropriate	Percentage reduction goal / Estimated demand elasticity
Calculate the revised price level	(% Change in price) x (Existing price) / Existing price
Calculate the revised demand level	(% Change in price) x (Elasticity value)
Estimate revised revenues under the revised price based on expected demand reductions	(Revised demand) x (Revised price)
Calculate revenue requirements based on reductions in variable costs resulting from reductions in demand	(Fixed costs) + (Variable costs at revised demand level)
Compare revised revenues with original revenues	(Revised revenues) - (Original demand x original price)
Select a rate structure that achieves the demand reduction goal while recovering allowable water system costs	In allocating costs, the impact of the rate structure on user demand and revenues for specific customer classes must be considered
Evaluate the need for special ratemaking provisions (such as cost-recovery or lost-revenue mechanisms)	Potential revenue instability can be addressed with additional rate structure modifications (e.g., revenue adjustment mechanisms)

Source: Adapted in part from American Water Works Association, *Before the Well Runs Dry: Volume 1--A Handbook for Designing and Local Water Conservation Plan* (Denver, CO: American Water Works Association, 1984).

policymaking concerns. Selecting a conservation rate structure is comparable to selecting any rate form in terms of the type of evaluation standards applied.[29]

Metering Water Service

Pricing water service depends on the practice of metering water-service customers. As mentioned in chapter 2, New York City features universal metering in its demand management strategy.[30] Since water consumption varies significantly with the presence of meters, metering policies are very relevant to water planners. By one estimate, the introduction of meters can produce a 20 percent savings in water use.[31] A study of submetering of water customers in apartment buildings, condominiums, and mobile home parks, suggested that although additional costs are incurred by utilities, water savings could range from 20 to 40 percent.[32] Metering and submetering also can assist in a water utility's leak-detection efforts. But perhaps most importantly, metering provides utilities with the opportunity to manage demand through pricing.

Basic Conservation Rate Structures

All water rates have some orientation toward conservation because charging for water use, in contrast to providing free water service or subsuming the price in rents or other

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[29] D. S. Hasson, "Selecting a Conservation Rate Structure," in *Proceedings of Conserv93.* (Denver, CO: American Water Works Association, 1993).

[30] See Anthony J. Blackburn, *The Impact of Metered Billing for Water and Sewer on Multifamily Housing in New York* (New York: New York City Department of Environmental Protection and New York City Rent Guidelines Board, 1994).

[31] California Department of Water Resources, *WaterPlan: Water Conservation Assumptions* (Sacramento, CA: California Department of Water Resources, 1989).

[32] Theodore C. Schlette and Diane C. Kemp, "Setting Rates to Encourage Water Conservation," *Water/Engineering and Management* 138, no. 3 (May 1991): 25-29.

charges, induces consumers to make sensible water-use choices.[33] More specifically, metered (and submetered) water rates incorporating a commodity charge are conservation-oriented since users pay increasing bills with increasing usage. Anecdotal stories abound about how water can be wasted when customers are not required to pay for their usage. At higher prices, the inclination to waste water is further discouraged. Martin and Wilder, in a study of water pricing for Columbia, South Carolina, found that both water usage and service terminations decline with increasing water rates.[34] Despite the efficiency effects of metering and pricing in general, some rate structures (such as increasing-block rates) have a stronger conservation orientation than other rate structures (such as uniform or decreasing-block rates).

Each of the basic rate design alternatives used by water utilities, depicted in figure 3-2, have implications for managing revenues and cash flows in the context of achieving water conservation goals.[35] Decreasing-block (or declining-block) rates, in which the applicable unit price declines with higher usage blocks, generally has been viewed as discouraging conservation.[36] The uniform rate (or uniform-commodity rate), in which a single rate applies to all consumer usage, has been viewed as more conservation-oriented than the decreasing-block structure. The increasing-block (or inclining or inverted-block) rate form, in which the applicable unit price increases with higher usage blocks, has been viewed as one of the more conservation-oriented rate structures.

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[33] John Farnkopf, et al., "Characteristics of Conservation-Oriented Rates," a paper presented at the Annual Conference of the American Water Works Association in Vancouver, British Columbia (1992).

[34] Randolph C. Martin and Ronald P. Wilder, "Residential Demand for Water and the Pricing of Municipal Water Services," *Public Finance Quarterly* 20 (January 1992): 93-102.

[35] Beecher and Mann, *Cost Allocation.*

[36] On the other hand, with decreasing-block rates the utility may have less incentive to promote sales. See chapter 4.

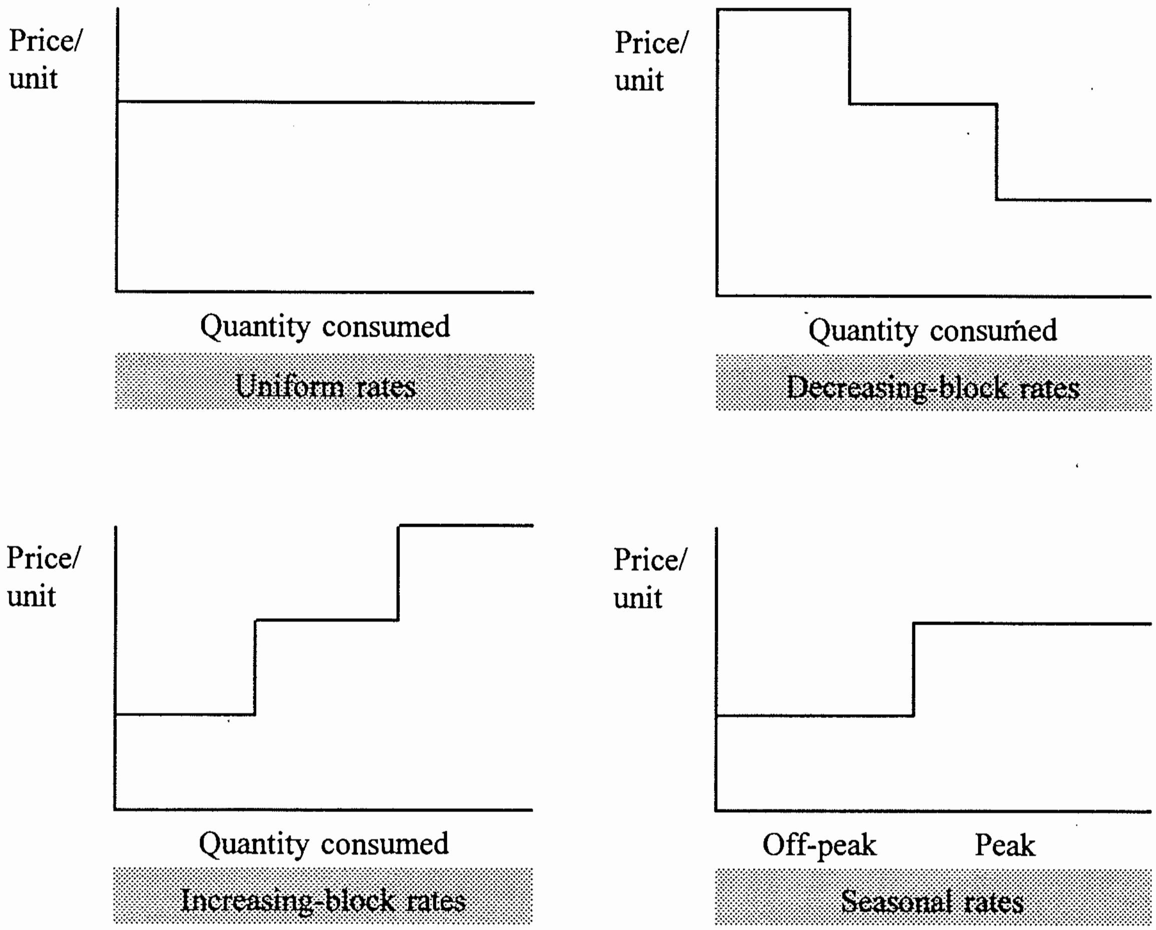

Figure 3-2. Basic water utility rate structures.

Additionally, any of the three basic rate forms can be combined with a seasonal rate structure to reflect variations in costs associated with peak demand patterns. Seasonal rates can be based on either incremental or embedded costs. Applied in the context of marginal-cost or incremental-cost considerations, seasonal rates can be used to promote economic efficiency. With seasonal pricing, customers pay higher rates during periods of peak demand (usually the summer) than they do during off-peak periods (usually the winter).[37] More complex and nonlinear rate structures reflecting these principles also can be considered. For example, decreasing blocks could be applied during off-peak seasons and increasing blocks could be applied to peak seasons of demand (figure 3-3). However, in practice, examples of this kind of ratemaking generally are not found in the water sector.

Water utility rate structures can be made more conservation-oriented through several approaches. As noted above, a recent trend has been to substitute decreasing-block rates with uniform or increasing-block rates. Some water utilities with substantial seasonal peaks have begun to implement seasonal rate structures. In some cases, more modest rate structure modifications have been made. For example, reducing the number of usage blocks in a decreasing-block rate structure (that is, rate flattening) can be considered a conservation-oriented rate strategy.

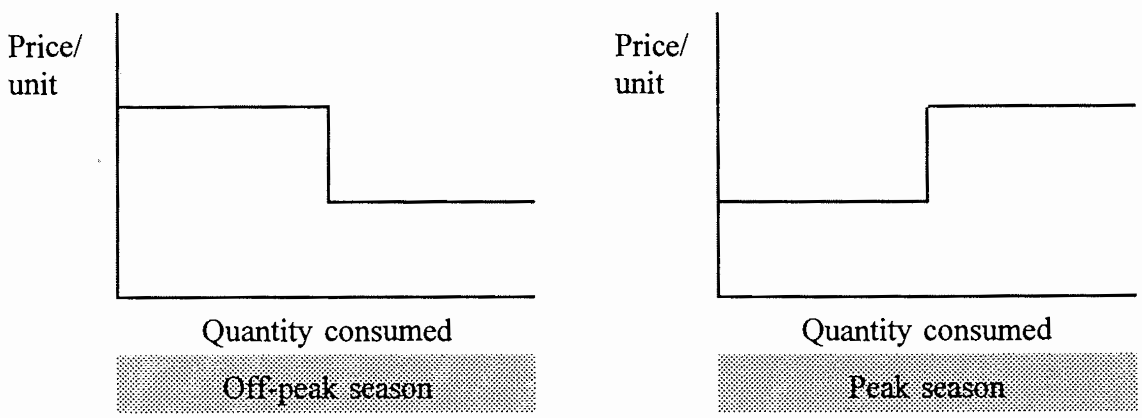

Figure 3-3. Example of a nonlinear rate structure.

[37] Three seasons, with no customer classes, have been used for ratemaking in Phoenix, Arizona. An evaluation found larger differences in peaking characteristics within classes than between classes. The city also has implemented a special environmental fee to pay for improvements associated with federal drinking water standards. See Jefferey S. DeWitt, "The Evolution of Water Rates in Phoenix, Arizona," in *Proceedings of Conserv93* (Denver, CO: American Water Works Association, 1993).

Alternative Conservation Rate Structures

Although uniform, increasing-block, and seasonal rates are the basic rate forms that promote water conservation, additional variations in rate design can be identified for potential application. A summary of conservation-oriented rate structures appears in table 3-3. The table describes the basic features for the following structures: metered service, uniform rates, increasing-block rates, seasonal rates, excess-use rates, indoor-outdoor rates, sliding-scale rates, scarcity pricing, spatial pricing, and penalties. Each form can be appropriate under certain circumstances, but the use of these alternatives also depends on the metering and billing capability of the utility. Universal metering is probably an appropriate goal for all utilities. The use of penalties, on the other hand, probably should be limited to extreme emergency situations. The use of more sophisticated rate structures, such as the excess-use or sliding-scale forms, should be evaluated in terms of the marginal costs and benefits associated with implementation. Water utilities also can promote conservation through the use of a surcharge or capacity deferral benefit.[38] Calculating the conservation surcharge involves one of several methods for estimating marginal cost in water supply.[39] The conservation surcharge is derived from the cost savings associated with conservation--the costs avoided by eliminating excess or discretionary usage. The end result is a commodity charge reflecting the costs that would be avoided if consumers lowered their level of demand. Determining the appropriate value for the conservation surcharge involves two steps: (1) identifying discretionary water consumption and (2) estimating the cost consequences of having consumers continue their long-term usage patterns at levels that include this discretionary usage.

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[38] Patrick C. Mann and Don M. Clark, "Water Costing, Pricing and Conservation," in *Proceedings of the Eighth Biennial Regulatory Information Conference* (Columbus, OH: The National Regulatory Research Institute, 1992). See also, Beecher and Mann, *Meeting Water Utility Revenue Requirements,* chapter 6.

[39] Beecher and Mann, *Cost Allocation and Rate Design.*

TABLE 3-3
A COMPARISON OF CONSERVATION-ORIENTED RATE STRUCTURES

Rate	Definition	Objectives
Metered service	Customer bills vary with water usage	Send a price signal to customers, promoting efficiency and discouraging waste
Uniform rates	Price per unit is constant as consumption increases	Reduce average demand
Increasing-block rates	Price per block increases as consumption increases	Reduce average (and possibly peak) demand
Seasonal rates	Prices during season of peak use are higher than off-peak season	Reduce seasonal peak demand
Excess-use rates	Prices are significantly higher for above-average use	Reduce peak demand
Indoor/ outdoor rates	Prices for indoor use are lower than prices for outdoor use	Reduce seasonal peak demand associated with outdoor use, which is considered more price-elastic
Sliding-scale rates	Price per unit for all water-use increases based on average consumption	Reduce average (and possibly peak) demand
Scarcity pricing	Cost of developing new supplies is attached to existing use	Reduce average use
Spatial pricing	Users pay for the actual cost of supplying water to their establishments	Discourage new or difficult-to-serve connections
Penalties	Charges certain customers a prespecified amount for exceeding allowable limits of water use	Reduce peak demand and discourages wasteful water use

Source: Authors' construct.

A conservation surcharge unbundles water usage in excess of average or normal levels and identifies the incremental cost associated with that usage. The conservation surcharge signals the opportunity cost associated with the consumer's decision to continue discretionary usage. The conservation surcharge can stand alone and thus be appended to a variety of rate forms based on either embedded or marginal cost. Revenues from the conservation surcharge can be placed in a dedicated deferred credit account to offset future costs incurred by the water utility in implementing conservation programs. In essence, the conservation surcharge can be separate from the revenue requirements of the water utility. The conservation surcharge provides a forward-looking conservation signal and complements least-cost planning, particularly if the accumulated funds from the conservation surcharge are used to finance conservation programs. Because the conservation surcharge is external to basic revenue requirements, it provides an efficient price signal without creating revenue deficiency. In other words, basic utility revenue requirements are covered and only the revenues associated with the surcharge are potentially unstable.

A chief benefit of conservation surcharges is that they reconcile embedded-cost and marginal-cost ratemaking principles, while providing funds for utility conservation programs. Consumers who elect to conserve avoid paying for the capacity that is linked to excess usage; consumers who elect not to conserve directly fund the capacity that ultimately will be necessary to meet the excess demand. In either case, consumer choice is maintained.[40] On the downside, surcharges can be complicated to implement, administer, monitor, and evaluate. Surcharges can cause revenue instability and result in excess earnings. A major potential barrier to their use is that regulators usually find it difficult to permit a rate mechanism that is external to the traditional determination of revenue requirements.

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[40] By contrast, consumer choices are limited when mandatory water-use restrictions are imposed by the utility.

Robert A. Collinge has proposed a similar rate form, which he refers to as a revenue-neutral "feebate" system to help utilities achieve water conservation goals.[41] The system consists of three parts: (1) a simple rate structure designed to achieve revenue neutrality while recovering the utility's fixed and average variable costs; (2) an entitlement program providing a baseline amount of water to each customer at the standard rate based on variables independent of ongoing usage, summing to the utility's intended supply amount; and (3) feebates in the forms of offsetting penalties assessed to customers using water above their entitlement and rebates to customers using water below their entitlement. According to Collinge, the result is that "water guzzlers" pay for the privilege of overconsumption, while "water frugal" customers are rewarded for their conservation efforts. Like any other conservation program, the success of a feebate system will depend largely on consumer information and awareness. However, some economists will argue that the feebate is equivalent to a price reduction, which could lead to the unintended consequence of increased water use.

Trends in Water Pricing

The variety of water utility rate structures implemented or under consideration seems to be expanding, both for nonregulated systems and commission-regulated systems.[42] Informed observers expect this trend to continue through the present decade.[43] Concerns about both equity and efficiency in water utility ratemaking also seem to be growing.

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[41] Robert A. Collinge, "Optimal Conservation by Municipal Water Customers: A Revenue-Neutral 'Feebate' System," in *Proceedings of Conserv93* (Denver, CO: American Water Works Association, 1993), 707-17. See also, Robert A. Collinge, "Revenue-Neutral Water Conservation: Marginal Cost Pricing with Discount Coupons," *Water Resources Research* 28, no. 3 (March 1992): 617-22.

[42] On the diversity of commission-approved rate structures, see chapter 5.

[43] David F. Russell and Christopher P. N. Woodcock, "What Will Water Rates be Like in the 1990's," *Journal American Water Works Association* 84 (September 1992): 68-72; Richard D. Giardina, "Conservation Pricing Trends and Examples," in *Proceedings of Conserv93* (Denver, CO: American Water Works Association, 1993).

As costs for the water supply industry rise, it is no wonder that cost-allocation and rate-design alternatives will get increasing attention. The magnitude of the recent rate increases (in some cases, more than twice that of the overall rate of inflation) have forced these issues to the forefront both for water utility managers and economic regulators. Traditional rate structures have drawn fire from critics who suggest that they do not send adequate pricing signals. A frequently noted trend in the water sector in recent years is the decline in the use of decreasing-block rates, matched by expanded use of uniform and increasing-block rate structures.[44] In addition, many water utilities have incorporated seasonal variations within their uniform, decreasing-block, or increasing-block rate structures. As discussed in chapter 5, some state (and interstate) regulatory commissions have begun to encourage conservation-oriented water rate structures. In sum, the rate design capability of the water supply industry appears to be evolving and maturing in some significant ways.

The Effectiveness of Conservation Rates

As discussed further below, researchers have analyzed the effectiveness of conservation-oriented rate structures for a number of specific water service territories. Nieswiadomy and Molina conducted a time-series analysis of water demand for consumers in Denton, Texas for 1976-1985.[45] Their demand models employed two price variables: marginal price and the ratio of average price to marginal price. Price sensitivity was estimated for decreasing-block rates (in effect for 1976-1980) and increasing-block rates (in effect for 1981-1985). The implication of this analysis was that consumers respond to average price when confronted with decreasing-block rates and respond to marginal price when confronted with increasing-block rates.

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[44] Ellen M. Duke and Angela C. Montoya, "Trends in Water Pricing: Results of Ernst & Young's National Rate Survey," *Journal American Water Works Association* 85 (May 1993): 55-61. See also, Jacob Boomhouwer and Karyn L. Johnson, "California Water Rate Structures are Changing From Uniform to Tiered," in *Proceedings of Conserv93* (Denver, CO: American Water Works Association, 1993).

[45] Michael L. Nieswiadomy and David J. Molina, "A Note on Price Perception in Water Demand Models," *Land Economics* 67 (August 1991): 352-359.

In a recent study, Jordan evaluated the effects of a conservation-oriented rate change in Spaulding County, Georgia. In January 1991, the water authority introduced increasing-block rates that resulted in a 5 percent decline in per capita water use and a 21 percent increase in utility revenues. During the same time period, 6 percent growth in the number of customers resulted in merely a 1 percent increase in total water use.[46] According to Jordan, the fact that water usage is relatively insensitive to changes in price can actually work to the advantage of utilities in terms of meeting revenue requirements.

Cuthbert analyzed the effectiveness of conservation rates for Tucson, Arizona for 1977-1986.[47] Tucson initiated a seasonally-differentiated increasing-block rate structure for single-family residential customers in 1977. The results for the single-family residential class were impressive. Water use for the residential class declined from 60 percent of total use in 1978 to 53 percent in 1986. The implication of this specific study was that increasing-block rates can substantially reduce residential usage.

Mann and Clark examined the experience of Spring Valley Water Company (New York) with conservation rates.[48] Spring Valley initiated a seasonally-differentiated decreasing-block rate structure in 1980. The seasonal rate structure substantially affected per capita usage and on the timing of maximum-day and maximum-hour demand. Over a ten-year period, the ratio of peak-hour to average-day demand declined from 2.68 to 1.73 and the ratio of peak-day to average-day demand declined from 1.52 to 1.25. As noted earlier, water conservation rates can be effective in reducing water usage because the demand for water is not purely price-inelastic.

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[46] Jordan, "Rates: Consider Conservation Water Pricing."

[47] John Cuthbert, "Effectiveness of Conservation-Oriented Water Rates for Tucson, Arizona," *Journal American Water Works Association* 81 (March 1989): 65-73.

[48] Don M. Clark and Patrick C. Mann, *Testimony in PSC Case No. 89-W-1151 - Phase II* (Albany, New York: New York Public Service Commission), 1991.

Price Elasticity of Water Demand

Price elasticity measures the sensitivity of the quantity demanded of a good or service to changes in its price, controlling for variations in other significant factors. Mathematically, price elasticity is the ratio of the percentage change in quantity demanded to the percentage change in price. With an elasticity of -.30, for example, a 10 percent increase in price is associated with a 3 percent reduction in the quantity demanded.[49] In this example, all other things being equal, revenues would increase by 6.7 percent (110 percent of prices multiplied by 97 percent of quantity demanded).[50]

Since there is an inverse relationship between price and quantity demanded, price-elasticity coefficients will have negative values. If water usage is relatively responsive to rate changes, water demand is considered relatively price-elastic (the price-elasticity coefficients will have absolute values exceeding 1.0 (for example, -1.3). In contrast, if water usage is relatively unresponsive to rate changes, demand for water service is considered relatively price-inelastic (the price-elasticity coefficients will have absolute values less than 1.0 (for example, -0.3). However, a price-elasticity coefficient with a value less than 1.0 can be very meaningful with respect to both managing demand and meeting revenue requirements. A 10 percent increase in price leading to a 7 percent decrease in usage, for example, can be dramatic for a given water system.

Unfortunately, price elasticity is not always considered in the determination and allocation of utility revenue requirements. In effect, water demand may be treated as perfectly price-inelastic and price-induced usage changes may be ignored. However, as long as price-elasticity coefficients are not zero, water usage will be affected by changes in price. Importantly, a revenue shortfall can occur regardless of whether water usage is highly

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[49] Whether the reverse holds, that a price decrease corresponds to a usage increase, is a matter of ongoing debate for this and other forms of elasticity.

[50] Mathematically, in an unregulated market environment, when demand is price-elastic, a price increase produces a revenue decrease; when demand is price-inelastic, a price increase produces a revenue increase. These results do not apply for the regulated water sector, where revenue effects are evaluated in comparison to revenue requirements.

responsive to price as long as ratemakers do not account for the effect of rate increases on usage and revenue reductions are not matched by cost reductions. Reasonably accurate demand forecasts that account for price-elasticity effects are essential for developing reasonably accurate revenue forecasts.

The relevance of price elasticity of demand to water utility managers and regulators is straightforward. Price elasticity is an essential tool for estimating the effect of a rate change on water demand and revenues.[51] The omission of price elasticity from rate design analysis creates the potential for revenue instability, as well as revenue shortfalls. Revenue shortfalls can be especially problematic if the rate structure is substantially modified (for example, shifting from decreasing-block rates to increasing-block rates), or if a large rate increase is implemented. The exclusion of price elasticity from a rate design analysis is a lesser problem if changes in the rate structure are modest.

The necessary consideration of price elasticity in water costing and rate design analysis is driven by the iterative process in which traditional water rate regulation takes place. That is, the rate setting process is a dynamic process in which the step of setting rates equal to an observed embedded cost can generate a cyclical pattern in which rate changes produce use changes, which further change certain unit costs, eventually leading to further rate changes. In brief, water demand affects cost of provision, in turn cost of provision determines rates, and in turn water rates affect usage. Importantly, these dynamics are at work *regardless* of whether prices are changed for efficiency or conservation reasons. In other words, *any* change in price (such as cost-based increases) can affect the quantity of water demanded.

Numerous studies of water demand have been conducted in the past three decades. The majority of these studies have focused on either aggregate municipal demand or on residential demand. Few studies have examined commercial and industrial demand. In general, the empirical results indicate that municipal and residential demands are price-inelastic. The demand for water tends to be relatively price-inelastic due to the essential

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[51] Beecher and Mann, *Cost Allocation and Rate Design.*

nature of water service and the lack of close substitutes.[52] An exception is when residential demand is disaggregated into seasonal (that is, outdoor use) and nonseasonal (that is, domestic or indoor use) components. Seasonal demands tend to be less price-inelastic than nonseasonal demands. Evidence also exists that price elasticity is positively correlated with water rate levels; that is, coefficients with higher absolute values are associated with higher rates, and vice versa.

In statistical studies, price may appear not to be a major determinant of water usage for a variety of reasons. The price effect on usage can be minimal if there is little change in real water prices over the long-term. Also, price impacts can seem to be overwhelmed by the effects of other demand parameters (such as temperature, rainfall, and household income). That is, the response of water usage to price can appear to be relatively small compared to the response of usage to other climatic or demographic factors. Measuring the responsiveness of water usage to changes in rates is further complicated by the timing or lags in consumer responses. Consumers might not immediately react to water rate increases. Finally, the conservation ethic among consumers in a given locality can enhance or impede water conservation responses. The existence of a strong conservation ethic among consumers can produce significant conservation effects even with modest rate increases.

Estimation Issues

Most water demand studies have employed cross-sectional data, thus yielding long-term price-elasticity estimates. Only a few studies have employed time-series data that focus on a specific geographical area experiencing substantial price changes over time. In addition, there are few reliable estimates of the price elasticities of peak and off-peak water demands, as well as the effect of conservation rates on water usage and peak demands. The econometric methods used in water demand studies are becoming increasingly sophisticated, which helps to assure that the statistical estimates are robust.

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[52] Water has no substitutes. Water delivery systems are substitutable to a degree. One example is drinking bottled water instead tap water. Another is using self-supplied well water instead of water supplied by a community system. Also, some uses of water can be substituted (such as sweeping the driveway instead of hosing it clean).

More than one hundred water demand studies were completed in the past three decades. A previous review of more than fifty of these demand studies concluded that the most likely price elasticity range for residential demand is -.20 to -.40 with price-elasticity coefficients for commercial and industrial demand being in the range of -.50 to -.80.[53] This review indicated that commercial and industrial users will tend to reduce usage in response to a rate increase by a larger proportion than residential users. Presumably, a large increase in water rates will induce some commercial and industrial users to seek alternative supplies.

The literature review also indicated that the price elasticity of municipal demand can be difficult to interpret unless the weights of the individual sectors (for example, residential, commercial, industrial, and governmental) can be specified. Each user class responds differently to rate increases. In this context, price-elasticity coefficients are comparable only for well-defined user classes. For example, one cannot justifiably compare residential class data with aggregate municipal data.

A review of the literature can provide standards of reference or benchmarks for establishing reasonable price-elasticity estimates. Obviously, relying on a literature review to estimate the price elasticity of demand is an imperfect approach. Existing studies will not help analysts predict unique responses to price changes in specific service areas. However, given the general nature of municipal water demand, comparing demand studies for similar service areas can be appropriate for benchmarking purposes.

Despite the overall result of relatively price-inelastic water demands, substantial variations in empirical results can be demonstrated. Boland provides several explanations for these different findings.[54] First, average-price and marginal-price variables will tend to generate different price-elasticity coefficients, particularly in the context of decreasing-block rates. Second, given the practice of levying wastewater charges on the basis of water usage,

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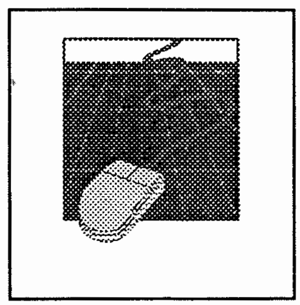
[53] Planning and Management Consultants, *Influence of Price and Rate Structures on Municipal and Industrial Water Use* (Fort Belvoir, VA: Institute for Water Resources, United States Army Corps of Engineers, 1984).

[54] John J. Boland, "Forecasting the Demand for Urban Water," in David Holtz and Scott Sebastian, eds., *Municipal Water Systems* (Bloomington, IN: Indiana University Press, 1978), 91-114.

estimation models incorporating sewage charges, in addition to water rates, produce more valid results than the estimation models that exclude wastewater charges.

Other problems with the calculation of price elasticity and the use of elasticity estimates are noteworthy.[55] Most water demand studies have used cross-sectional data that are presumed to yield long-run price-elasticity estimates. Only a few studies have used pooled time-series data that focus on a specific geographical area experiencing substantial rate changes over time. That is, data constraints have resulted in more estimates of long-run price elasticity than estimates of short-run price elasticity. In this context, specific cross-sectional studies can be flawed by incompatible accounting and operating data from different water utilities and by the lack of credible supporting demographic data. Specific time-series studies can be flawed by small sample sizes, infrequent price changes, and a lack of supporting demographic data.

Selected Water Demand Studies



One of the most important and lasting contributions to the literature on water demand was the compilation of empirical studies prepared for the U.S. Army Corps of Engineers.[56] An adaptation and update of this pathbreaking chronology (which included studies through 1978) appears in table 3-4. Of the many water demand studies that have been conducted in the past several decades, several are worthy of comment because of their substantial contribution to academic and practical knowledge about the price elasticity of water demand. Importantly, it is not uncommon for the results of one study to contradict the results of another in terms of statistical findings. Although the review can be used for benchmarking, the generalizability of specific findings is

[55] Ibid.

[56] Planning and Management Consultants, *Influence of Price*. See also, William O. Maddaus, *Water Conservation* (Denver, CO: American Water Works Association, 1987), 66.

limited. Some of the more recent water demand studies are highlighted below according to key variables, findings, and conclusions.

Research Findings

Rate Design

Researchers have found that water rate design can affect water usage. Stevens, Miller, and Willis conducted a cross-sectional analysis of 1988 water demand for eighty-five communities in Massachusetts.[57] Employing an average price variable, price elasticities were calculated for three rate structures: uniform rates, decreasing-block rates, and increasing-block rates. For uniform rates, price elasticities ranged from -.10 to -.43. For decreasing-block rates, price elasticities ranged from -.40 to -.69. For increasing-block rates, price elasticities ranged from -.42 to -.54. The implications of this analysis were that price elasticities are not substantially affected by type of rate design and that the level of rates is more important than rate structure in affecting water usage. Similarly, Young, Kinsley, and Sharpe, in a study of residential consumers of the Washington Suburban Sanitary Commission for 1974-1979, found that an increasing step rate was a very powerful tool in reducing water usage.[58] In a step rate, the increasing rate applies to all water usage and not simply to the last usage increment, thus producing much higher average rates for high-volume users than for low-volume users. The implication of this particular study was that increases in rate levels substantially reduce water usage, particularly among high-volume consumers.

Another study confirmed the importance of rate levels. That is, changes in higher rates produce greater usage responses than changes in lower rates. Martin and Thomas conducted a cross-sectional analysis of residential water demand, using 1978-1979 data for

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[57] Thomas H. Stevens, Jonathan Miller and Cleve Willis, "Effect of Price Structure on Residential Water Demand," *Water Resources Bulletin* 28 (August 1992): 681-685.

[58] C. E. Young, K. R. Kinsley and W. E. Sharpe, "Impact on Residential Water Consumption of an Increasing Rate Structure," *Water Resources Bulletin* 19 (February 1983): 81-86.

four cities including Tucson and Phoenix, Arizona.[59] A comparison of demand data from the four cities indicates a long-run price elasticity for residential water demand of approximately -.50, over a wide range of prices and also indicates that residential water demand tends to become more price-elastic with higher water prices.

Fixed Charges

Increases in fixed water charges (for example, an increase in service charges or minimum charges) can induce consumer usage responses. Billings and Agthe examined residential water demand in a time-series study of Tucson, Arizona for 1974-1977.[60] Their models incorporated marginal price as well as a rate variable reflecting fixed charges. The latter variable was measured by the total water bill minus the hypothetical bill if all usage were sold at the marginal price. The overall price elasticities ranged from -.39 to -.63. The marginal price elasticities ranged from -.27 to -.49. The conclusion of this study was that the addition of a variable measuring fixed charges increases overall price-elasticity coefficients. A supplemental analysis by the same research team (and colleagues) again incorporated marginal price as well as the fixed charges variable.[61] The conclusion of this analysis was that the addition of a variable reflecting fixed charges in the demand model leads to higher short-run and long-run price-elasticity coefficients.

Average v. Marginal Prices

Analysts have hypothesized that the selection of the price variable can affect price-elasticity results. Jones and Morris conducted a cross-sectional study of residential water

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[59] William E. Martin and John F. Thomas, "Policy Relevance in Studies of Urban Residential Water Demand," *Water Resources Research* 22 (December 1986): 1735-1741.

[60] Bruce R. Billings and Donald E. Agthe, "Price Elasticities for Water: A Case of Increasing Block Rates," *Land Economics* 56 (February 1980): 73-84.

[61] Donald E., Agthe, R. Bruce Billings, John L. Dobra and Kambizz Raffiee, "A Simultaneous Equation Demand Model for Block Rates," *Water Resources Research* 22 (January 1986): 1-4.

demand for Denver, Colorado.[62] Their analysis, based on 1976 data for 326 water consumers, employed models using average price as well as marginal price. Price elasticities ranged from -.18 to -.34 in the average price models and ranged from -.14 to -.44 in the marginal price models. This study indicated that the use of average price rather than marginal price may not yield substantially dissimilar price-elasticity coefficients.

Williams and Suh conducted a cross-sectional analysis, based on 1976 data for eighty-six water systems.[63] They used three rate variables to calculate price elasticities: marginal price, average price, and monthly water bill. For residential demand, price elasticity was -.25 for marginal price and -.48 for average price with bill elasticities ranging from -.18 to -.32. For commercial demand, price elasticity was -.14 for marginal price and -.36 for average price with bill elasticities ranging from -.23 to -.34. For industrial demand, price elasticity was -.44 for marginal price and -.74 for average price with bill elasticities ranging from -.72 to -.98. The conclusion of this analysis was that the use of average water rates shows higher usage responses than when marginal water rates are incorporated in the model, particularly in the context of decreasing-block rates.

In the multiple regression analysis described in the previous chapter, Billings and Day used a pooled time-series/cross-sectional analysis for data on three utilities in the Tucson area.[64] Two residential demand models incorporating increasing-block rate structures were estimated. The analysis focused on the period 1974 through 1980, a period in which Tucson experienced substantial reductions in water usage, due both to conservation pricing and programs. The estimates of long-run price elasticity averaged -.72. For the marginal-price model, elasticity averaged -.52; for the average-price model, elasticity averaged -.70. The investigators found that the average-price model had superior explanatory power when

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[62] C. Vaughn Jones and John R. Morris, "Instrumental Price Estimates and Residential Water Demand," *Water Resources Research* 20 (February 1984): 197-202.

[63] Martin Williams and Byung Suh, "The Demand for Urban Water by Customer Class," *Applied Economics* 18 (December 1986): 1275-1289.

[64] R. Bruce Billings and W. Mark Day, "Demand Management Factors in Residential Water Use: The Southern Arizona Experience," *American Water Works Association Journal* 81, no. 3 (March 1989): 64.

incomes are high and water prices are low; the model incorporating marginal prices and a rate premium (reflecting the difference between the actual bill and what the customer would pay if all water were sold at the marginal price) had superior explanatory power when prices were higher or incomes were lower, and as water bills approached 2 percent or more of household income.

Wastewater Charges

The incorporation of wastewater treatment rates in the demand estimation model can affect price-elasticity estimates. This is a relatively recent discovery. Griffin and Chang conducted a time-series analysis of water demand for thirty Texas communities for 1983-1985.[65] The price variables in the model included water dependent sewer charges. Price elasticity was -.19 for winter and -.37 for summer. Excluding sewer charges, price elasticity was -.10 for winter and -.30 for summer. The implication of this analysis was that the omission of water dependent sewer rates from the model can bias the price-elasticity results by reducing the absolute values of the price-elasticity coefficients. Future demand studies might also include an estimate of stormwater treatment charges, which are now affecting many regions of the country. This type of analysis would help in the assessment of consumer responses to total water sector costs.

Customer Class

Each user class responds differently to water rate changes. Thus, price elasticities are comparable only for well-defined users classes, such as single-family residential, multi-family residential, commercial, industrial, and governmental. For example, the previously noted analysis of Williams and Suh clearly indicated that industrial water demand is substantially more price-responsive than residential water demand.[66] Schneider and Whitlatch conducted a

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[65] Ronald E. Griffin and Chan Chang, "Pretest Analysis of Water Demand in Thirty Communities," *Water Resources Research* 26 (October 1990): 2251-55.

[66] Williams and Suh, *Applied Economics,* 1275-89.

pooled time-series/cross-sectional analysis of water demand for metropolitan Columbus, Ohio.[67] The analysis, employing data for 1959-1976, covered sixteen communities served by the Columbus water system. Price elasticities were calculated for five customer classes (residential, commercial, industrial, government, and schools) as well as for total demand. For residential customers, price elasticity was -.11 for the short-run and -.26 for the long-run. For commercial users, price elasticity was -.24 for the short-run and -.92 for the long-run. For industrial users, price elasticity was -.11 in the short-run and -.44 for the long-run. For government units, price elasticity was -.44 for the short-run and -.78 for the long-run. For schools, price elasticity was -.38 for the short-run and -.96 for the long-run. And for total demand, price elasticity was estimated to be -.12 for the short-run and -.50 for the long-run. The conclusion of this analysis was that both short-run and long-run price elasticities vary substantially over customer classes.

Indoor v. Outdoor Use

Residential demand can be disaggregated into two components, indoor usage or outdoor usage. These two components of residential demand have different sensitivities to rate changes. Howe and Linaweaver performed a cross-sectional analysis of residential water demand incorporating thirty-nine urban areas.[68] The price elasticity of total residential demand was estimated to be -.41 using a weighted average of the domestic and irrigation elasticities. The price elasticity for residential domestic demand was estimated to be -.23. The price elasticity for domestic irrigation demand was estimated to be -.70 in the western United States and -1.57 in the eastern United States. This analysis suggests that domestic demand is highly price-inelastic and that irrigation demand is price-inelastic in the west but is price-elastic in the east.

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[67] Michael L. Schneider and E. Earl Whitlatch, "User-Specific Water Demand Elasticities," *Journal of Water Resources Planning and Management* 117 (January-February 1991): 52-73.

[68] Charles W. Howe and F. Pierce Linaweaver, "The Impact of Price on Residential Water Demand and its Relationship to System Design and Price Structure," *Water Resources Research* 3 (First Quarter 1967): 13-32.

Howe, in a cross-sectional analysis, dissagregated residential water demand into winter and summer (rather than into domestic and irrigation) components.[69] The price elasticity for winter demand was calculated as -.06. Summer price elasticity was estimated to be -.43 for Western U.S. and -.57 for Eastern U.S. The implications of this study is that again seasonal usage is less responsive to rate changes in the West than in the East.

Carver and Boland examined seasonal variations in municipal water demand using pooled time-series/cross-sectional data.[70] Their sample was thirteen water systems primarily serving residential consumers in the Washington D.C. area; the period of analysis was 1969-1974. The pooled analysis generated short-run price elasticities ranging from -.02 for winter demand to -.11 for summer demand, and long-run price elasticities ranging from -.11 for summer demand to -.70 for winter demand. The implication of this analysis was that summer usage is more responsive to rate changes than winter usage, both in the short-run and in the long-run.

A study of the water systems within the South Florida Water Management District found residential price elasticities to vary according to price levels and property values.[71] Elasticities for single-family homes were estimated to range from -0.01 to -0.90. However, no discernible relationship between price and water use could be found for residential apartments (the elasticity coefficient was -0.00). The study confirmed the general belief that indoor water use is less price-elastic. The virtually price-inelastic demand found for apartment dwellers could be attributed to master metering. Although one might expect that apartment owners who are responsible for bill payment would be motivated to reduce water costs by installing more efficient fixtures and appliances, the results of the analysis did not detect this type of response.

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[69] Charles W. Howe, "The Impact of Price on Residential Water Demand; Some New Insights," *Water Resources Research* 18 (August 1982): 713-716.

[70] Philip H. Carver and John J. Boland, "Short-Run and Long-Run Effects of Price on Municipal Water Use," *Water Resources Research* 16 (August 1980): 609-616.

[71] John B. Whitcomb, Jay W. Yingling, and Marvin Winer, "Residential Water Price Elasticities in Southwest Florida," in *Proceedings of Conserv93* (Denver, CO: American Water Works Association, 1993), 695-701.

Peak v. Off-Peak

Based on variations in indoor and outdoor use, it is no wonder that water demand can vary between peak and off-peak water periods. Lyman conducted a time-series analysis of water demand for thirty households in Moscow, Idaho for 1983-1987.[72] Price elasticity was estimated for both short-run and long-run, as well as for peak demand and off-peak demand. For short-run peak demand, price elasticities ranged from -1.38 to -2.02. For long-run peak demand, price elasticities ranged from -2.60 to -3.33. For short-run off-peak demand, price elasticities ranged from -.40 to -.43. For long-run off-peak demand, price elasticities ranged from -.63 to -.71. The implications of this analysis were that both short-run and long-run peak water demand is more price-elastic than off-peak demand. Further, the study found that the price sensitivity of peak demand affects off-peak demand when consumers purchase and use more water-efficient appliances.

Price elasticity during periods of drought also is a significant issue because of implications of peak usage. Moncur analyzed single-family residential demand in Honolulu using a pooled time-series/cross-sectional analysis.[73] Price, income, household size, and rainfall variables were included in the regression as well as a dummy variable representing a water restriction program. Even during periods of serious drought, it was found that a 40 percent increase in the marginal price of water would result only in a 10 percent reduction in water use (an elasticity coefficient of -.25).

Short-Term v. Long-Term

Long-term responsiveness to changes in price is likely to be greater than short-term responsiveness. This finding, which is particularly true for residential consumers, can be attributed partly to the assumption that consumers in the long term have more opportunity to use water efficiently. Agthe, Billings, Dorba, and Raffiee conducted a time-series analysis of

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[72] R. Ashley Lyman, "Peak and Off-Peak Residential Water Demand," *Water Resources Research* 28 (September 1992): 2159-2167.

[73] J. E. Moncur, "Urban Water Pricing and Drought Management," *Water Resources Research* 23, no. 3 (1987): 393-98.

residential water demand for Tucson, Arizona for 1974-1980.[74] Employing marginal price, their estimating models calculated both short-run and long-run price elasticity. Short-run price elasticity was estimated to be -.50; long-run price elasticity was estimated to be -.87. The implication of this study was clearly that long-term residential water demand is more sensitive to price than short-term residential water demand.

Regional and Zonal Variations

As previously indicated, usage responses to rate changes vary across geographical areas. Foster and Beattie conducted a cross-sectional study of 218 water utilities in the United States.[75] The analysis, employing 1960 data, categorized water systems into six regions and calculated the price elasticity of residential demand for each region. The price elasticities ranged from -.30 in the Midwest to -.43 in New England. Other price elasticities were -.36 for the Southwest and -.38 for the South. The price-elasticity estimates for the Rocky Mountain region (-.58) and for the Pacific Northwest (-.69) were adversely affected by very small samples. The implications of this analysis include that it is difficult to formulate a residential water demand model for the entire United States and that usage responses to rate changes are greater in New England than in the more arid Southwest.

Some elasticity studies have segmented demand into areas of water usage within a utility's territory. Weber, in a pooled time-series/cross-sectional analysis of the East Bay Municipal Utility District (EBMUD), in California, generated estimates of long-run price elasticity for summer water demand.[76] His demand model employed marginal water price and focused on the period 1981 through 1987. The analysis used data for twelve pressure zones in the EBMUD service areas; price-elasticity estimates ranged from -.10 to -.25.

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[74] Donald E. Agthe, et al., "A Simultaneous Equation Demand Model for Block Rates," *Water Resources Research* 22 (January 1986): 1-4.

[75] Henry S. Foster and Bruce R. Beattie, "On the Specification of Price in Studies of Consumer Demand under Block Price Scheduling Urban Residential Water Demand for Water in the United States," *Land Economics* 55 (February 1979): 43-58.

[76] Jack A. Weber, "Forecasting Demand and Measuring Price Elasticity," *American Water Works Association Journal* 81, no. 5 (May 1989): 57-65.

The Role of Public Education

Conservation education programs can be as important in reducing water usage as rate increases. Nieswiadomy conducted a cross-sectional analysis of water demand for 430 water utilities in the United States.[77] Using 1984 data, the demand models used several price variables, as well as variables reflecting utility-sponsored conservation and public education programs. For the marginal-price model, price elasticities ranged from -.29 to -.45; for the average-price model, price elasticities ranged from -.22 to -.60. One finding of this study was that conservation programs, by themselves, may not affect water usage. However, in the West, public education has influenced water usage more than changes in rates. Agthe, Billings, and Dworkin, in a study of 644 households in Tucson, Arizona, found that whether or not consumers are knowledgeable about the water rate structure is an important factor in water conservation.[78] For example, consumers who were aware of the increasing-block rate structure believed that it reduced water usage. It should be noted that the majority of the consumers surveyed were not aware of either the existence of an increasing-block rate structure or seasonal rate differentials (both of which had been in place for seven years prior to the survey). The important implications of this analysis were that informed consumers take initiatives to reduce water usage while uninformed consumers are unlikely to engage in conservation, given any restructuring of rates. Another potentially important factor is the long-run effect of education on the very shape and level of the demand curve, not just the movement between points on the existing curve.

If water rates lag behind rates of inflation, this can induce consumers to increase usage. For example, if the actual price of water remains constant for several years after a rate increase, the real price of water can revert to (or possibly decline below) its original level. Martin and Kulakowski examined water policy for Tucson, Arizona over the extended period

[77] Michael L. Nieswiadomy, "Estimating Urban Residential Demand: Effect of Price Structure, Conservation, and Education," *Water Resources Research* 28 (March 1992): 609-615.

[78] Donald E. Agthe, R. Bruce Billings and Judith M. Dworkin, "Effects of Rate Structure on Household Water Use," *Water Resources Research* 24 (June 1988): 627-630.

of 1965 to 1988.[79] They found that conservation information and education programs were not as effective in reducing water usage as increases in the real price of water. That is, water usage is more affected by increases in real water prices than by increases in actual or nominal water rates. Water rate increases in excess of inflation rates could have more significant conservation effects.

Implications

In a regulatory framework, the key price-elasticity issues center on the validity, relative importance, and proper interpretation of elasticity estimates and implications for both demand and revenues. Price elasticities for different customer classes also must be considered. For example, the water demand patterns for large-volume customers generally are more price-elastic than those for residential and commercial customers. The repeal of volume discounts, combined with a rate increase, will most likely trigger a response by large-volume customers. These users might try to reduce their water consumption through efficiency improvements or consider bypassing the water supplier in favor of self-supply. In extreme cases, they might seek to relocate, although this reaction is rarely justified on purely economic grounds. Regardless of which option is chosen, the result for the utility is revenue instability and shortfalls. These problems are made worse when elasticity estimates are excluded from the rate design analysis prior to setting prices. In other words, assumptions about the interaction between demand elasticities and alternative rates structures must be given careful consideration.[80]

A hypothetical example can illustrate the importance of price elasticity in rate design. The water system in this example has a sizable residential customer base and one very large industrial customer, in this case a brewery. The key assumptions are that the water utility has

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[79] William E. Martin and Susan Kulakowski, "Water Price as a Policy Variable in Managing Urban Water Use," *Water Resources Research* 27 (February 1991): 157-166.

[80] D. Comer and Richard Beilock, "How Rate Structures and Elasticities Affect Water Consumption," *American Water Works Association Journal* 74, no. 6 (June 1982): 285-287.

increased its tail-block rate by 50 percent and that the tail block incorporates 98 percent of the water usage of the brewery. Properly specified water demand analyses for the brewery industry have indicated that the long-run price-elasticity coefficients range from -.40 to -.60. In other words, a 10 percent increase in rates reduces brewery water usage by 4 to 6 percent.[81]

The result of the tail-block increase is a usage reduction in the range of 20 to 30 percent. Given that the brewery formerly paid $300,000 annually for water, the water utility cannot presume that water revenues from the brewery will increase to $450,000 (a 50 percent increase); most likely, brewery revenues will fall short of $400,000. If the price-elasticity effect on usage was not incorporated in the rate design analysis, the long-run result is a revenue shortfall for the utility. A corresponding result is that lost revenues needed to cover fixed costs could be made up through further rate increases.

The implications of omitting price elasticity from the rate design process are becoming more critical. Some emerging evidence suggests that the price sensitivity of water demand may be increasing over time (with increasing real water prices) and that conservation programs can influence the shape or nature of water demand curves. Thus, the price elasticities for all user classes. In this context, it is difficult to provide practical benchmarks for gauging how much effort should be spent on developing elasticity estimates for a given water service territory. However, common wisdom would suggest that for many water systems, the price of ignorance on this issue can be high. While it may not be cost-effective for all systems to conduct their own detailed demand studies, it seems sensible to use the existing research to develop benchmarks for assessing the potential impact of price changes on the quantity of water demanded.

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[81] The price elasticity for beer demand is not included in this analysis, but certainly should be a consideration to the brewery if it plans to pass along the water rate increase to beer consumers. Price-inelastic beer demand would be an advantage to the water utility (and other providers of beer ingredients). However, the demand for beer is not price-inelastic and the beer industry is highly competitive, so that breweries have strong incentives to hold down the cost of production.

In future demand studies, a number of complex issues will become increasingly challenging, such as: the changing magnitude of rate increases and total customer bills (for water, wastewater, and stormwater); the combination effects of the ability and willingness to pay for water service; the presence of realistic opportunities to conserve water and promote efficiency; the sense of urgency associated with water resource conservation; and the compound effect of prices and other variables in shaping the overall demand for water. Analysts must bear in mind that not every change in usage can be attributed to a change in price. However, the impact of price on the quantity of water demanded may become increasingly important, making the price-elasticity estimation more vital than ever.

TABLE 3-4
RESEARCH ON ESTIMATED PRICE ELASTICITY
FOR WATER DEMAND

Investigator	Year	Data (a)	Type of Demand	Elasticity
Gottlieb	1952	68 Kansas cities		-1.02
	1952	19 Kansas cities		-1.24
	1957	84 Kansas cities		-0.69
	1957	24 Kansas cities		-0.68
	1958	24 Kansas cities		-0.66
	1963	Kansas (CS)		-0.95 (mean)
Seidel & Baumann	1957	U.S. cities (CS)	$.45/1,000 gal	-0.12
Renshaw	1958	36 systems (CS)		-0.45
Fourt	1958	34 U.S. cities (CS)		-0.39
Heaver & Winter	1963	Ontario cities		-0.254
Wong, et al.	1963	N.E. Illinois (CS)		-0.31 (mean)
Hedges & Moore	1963	Northern California	Irrigation	-0.19
Howe & Linaweaver	1963-1965	21 cities	Domestic sewers	-0.23
			Seasonal use	-1.16
	1967	39 urban areas (CS)	Total residential	-0.41
			Residential domestic	-0.23
			Sprinkling, west	-0.70
			Sprinkling, east	-1.57
Gardner & Schick	1964	42 Northern Utah systems (CS)		-0.77
Flack	1965	54 western cities (CS)	$.45/1,000 gal	-0.12
		All cities (CS)	$.45/1,000 gal	-0.65
Ware & North	1965	634 Georgia households	Residential	-0.67

TABLE 3-4 (continued)				
Investigator	Year	Data (a)	Type of Demand (b)	Elasticity
Bain, Caves, & Margolis	1966	41 Northern California cities (na)		-1.10
			Irrigation	-0.64
	1966	41 California cities (CS)		-1.099
Conley	1967	24 Southern California cities (CS)		-0.625 (mean)
Bruner	1969	Phoenix, AZ		-0.33
Turnovsky	1969	19 Massachusetts towns (CS)		-0.225 (mean)
		Massachusetts (CS)	Industrial	-0.47 to -0.84
Burns, et al.	1970s	Stratified two-price comparison	Indoor use	-0.20 to -0.38
			Sprinkling	-0.27 to -0.53
Grima	1970	91 observations (CS)		-0.93
	1972	Ontario cities	Winter	-0.75
Wong	1970	Chicago, IL (TS, 1951-1961)		-0.15 (mean)
		Four large groups (CS)		-0.54 (mean)
Ridge, R.	1972	(CS)	Industrial, malt liquor	-0.30
			Industrial, fluid milk	-0.60
Young, R.A.	1973	Tucson, AZ (TS, 1946-1971)	Reanalysis	-0.20
DeRooy	1974	New Jersey (CS)	Chemical, cooling	-0.89
			Chemical, processing	-0.74
			Chemical, steam gen.	-0.74
Grunewald, et al.	1975	150 rural Kentucky cities (CS)		-0.92
Hogarty & McCay	1975	Blacksburg, VA (TS, 2 years)		-0.50 to -1.40
Pepe, et al.	1975	4 S. Carolina cities (TS, 2 and 3 years)		-0.00 to -0.51

TABLE 3-4 (continued)				
Investigator	Year	Data (a)	Type of Demand (b)	Elasticity
Camp. R.C.	1978	228 Mississippi households (CS)		-0.24 to -0.31
Carver, P.H.	1978	13 Washington, D.C., systems (TS/CS, 6 years)	Short-run	-0.00 to -0.10
	1978	Fairfax County, VA (TS, 4 years)	Innovative price structure	-0.02 to -0.17
Lynne, et al.	1978	Miami, FL (CS)	Department stores	-0.33
			Grocery stores	-0.89
			Hotels	-0.14 to -0.30
			Eating and drinking	-0.00 (c)
Foster & Beattie	1979	218 U.S. systems, 6 regions (CS, 1960)	Midwest	-0.30
			New England	-0.43
			Southwest	-0.36
			South	-0.38
			Rocky Mountain	-0.58
			Pacific Northwest	-0.69
Billings & Agthe	1980	Tucson, AZ (TS, 1974-1977)	Residential overall	-0.39 to -0.63
			Residential marginal	-0.27 to -0.49
Carver & Boland	1980	13 Washington, D.C. systems (TS/CS, 1969-1974)	Resid. short-run winter	-0.02
			Resid. short-run summer	-0.11
Carver & Boland (continued)	1980	13 Washington, D.C. systems (TS/CS, 1969-1974)	Resid. long-run winter	-0.70
			Resid. long-run summer	-0.11
Howe	1982	Regional U.S. (CS)	Residential winter	-0.06
			Residential summer, west	-0.43
			Residential summer, east	-0.57

TABLE 3-4 (continued)

Investigator	Year	Data (a)	Type of Demand (b)	Elasticity
Jones & Morris	1984	326 Denver, CO households (CS, 1976)	Average price models	-0.18 to -0.34
			Marginal price models	-0.14 to -0.44
Agthe, Billings, & Dorba, & Raffice	1986	Tucson, AZ (TS, 1974-1980)	Residential short-run	-0.50
			Residential long-run	-0.87
Martin & Thomas	1986	4 cities (CS, 1978-79)	Residential	-0.50
Williams & Suh	1986	86 systems (CS, 1976)	Residential marginal	-0.25
			Residential average	-0.48
			Resid. bill elasticity	-0.18 to -0.32
			Commercial marginal	-0.14
			Commercial average	-0.36
			Commercial bill elasticity	-0.23 to -0.34
			Industrial marginal	-0.44
			Industrial average	-0.74
			Industrial bill elasticity	-0.72 to -0.98
Moncur	1987	Honolulu, HI, including drought period (TS/CS 1980s)	Resid., marginal price	-0.25
Billings & Day	1989	Tucson, AZ, water department districts (TS/CS 1974-1980)	Res., combined long-run	-0.72
			Resid., marginal price	-0.52
			Resid., average price	-0.70
Weber	1989	East Bay Municipal District (TS/CS, 1981-1987)	Summer, long-run	-0.10 to -0.25
Griffin & Chang	1990	30 Texas communities (TS, 1983-1985)	Winter with sewer	-0.19
			Summer with sewer	-0.37
			Winter, no sewer	-0.10
			Summer, no sewer	-0.30

TABLE 3-4 (continued)				
Investigator	Year	Data (a)	Type of Demand (b)	Elasticity
Schneider & Whitlatch	1991	16 Columbus, OH communities (TS/CS, 1959-1976)	Residential short-run	-0.11
			Residential long-run	-0.26
			Commercial short-run	-0.24
			Commercial long-run	-0.92
			Industrial short-run	-0.11
			Industrial long-run	-0.44
			Government short-run	-0.44
			Government long-run	-0.78
			Schools short-run	-0.38
			Schools long-run	-0.96
			Total short-run	-0.12
			Total long-run	-0.50
Lyman	1992	30 households, Moscow, ID (TS, 1983-1987)	Short-run peak	-1.38 to -2.02
			Long-run peak	-2.60 to -3.33
			Short-run off-peak	-0.40 to -0.43
			Long-run off-peak	-0.63 to -0.71
Nieswiadomy	1992	430 U.S. water utilities (CS, 1984)	Marginal price	-0.29 to -0.45
			Average price	-0.22 to -0.60
Stevens, Miller, & Willis	1992	85 Massachusetts communities (CS, 1988)	Uniform rates	-0.10 to -0.43
			Decreasing-block	-0.40 to -0.69
			Increasing-block	-0.42 to -0.54
Whitcomb, Yingling, & Winer	1993	Southwest Florida Management District (TS/CS 1988-1992)	Single-family homes	-0.01 to -0.90
			Apartments	-0.00 (b)

Source: Authors construct based on Planning and Management Consultants, *Influence of Price and Rate Structures on Municipal and Industrial Water Use* (Fort Belvoir, VA: Institute for Water Resources, United States Army Corps of Engineers, 1984), updated for post-1978 studies.

(a) Type of data used for the statistical analysis: cross-sectional (CS), time-series (TS), or pooled time-series/cross-sectional (TS/CS).
(b) Not significantly different from zero.