POLITICALLY FEASIBLE, REVENUE SUFFICIENT, AND ECONOMICALLY EFFICIENT MUNICIPAL WATER RATES

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Water rates are designed to meet multiple objectives, typically resulting in trade-offs among the objectives of economic efficiency, revenue sufficiency, and related revenue stability. Standard theory of natural monopoly is extended here to explain why long-run marginal cost (LMC) can be greater than both average cost and short-run marginal cost (SMC) for municipal water utilities. The distinctions between "benign monopoly rates" and "marginal cost rate design" favor LMC over SMC as the basis for economically efficient rate design. Taking into account conservation investments by consumers, SMC rates are economically inefficient, except during temporary shortages. The City of Los Angeles adopted economically efficient, revenue sufficient, and revenue-stable water rates at the end of a prolonged drought. After the drought ended, Los Angeles (LA) modified the rate design, making the design politically feasible during normal rainfall years. Unique features in the LA rate design determine the allocation of consumer surplus among ratepayers, making the rate design politically feasible by sharing efficiency gains among customer classes. Revenue sufficiency and stability features in the rate design minimize adverse job effects on water utility management, reducing the frequency of rate hearings with an increasing block design. (*JEL* L51, L95, Q25, Q51)

I. INTRODUCTION

Objectives of municipal water rate design include economic efficiency of water use, revenue sufficiency, and related revenue stability, although it is commonly accepted that these objectives cannot be achieved simultaneously, requiring trade-offs among the objectives (American Water Works Association, 2000). A numerical example herein illustrates these objectives for residential water rate reform and another objective for political feasibility.

Water utilities are an example of natural monopoly, characterized in classic textbook fashion with declining long-run average cost (LAC) above long-run marginal cost (LMC). As urban population grows over time, municipal water utilities reach the capacity of their existing system and look for new sources of water typically more expensive than system average cost. The numerical example presented here shows a declining LAC curve with discontinuities at the capacities of each additional water supply project. Each additional project provides water at higher cost than the previous project, but LAC is declining within the capacity constraint for each project. For natural monopolies, long-run incremental cost pricing is economically efficient but results in monopoly profit, overturning the conventionally accepted outcome that with "increasing

ABBREVIATIONS

AF: Acre-Foot
AVC: Average Variable Cost
BU: Billing Unit
DWP: Department of Water and Power
EBMUD: East Bay Municipal Utility District
EC: Embedded Cost
HAC: Historical Average Cost
LA: Los Angeles
LAC: Long-Run Average Cost
LMC: Long-Run Marginal Cost
MAF: Million Acre-Feet
MIB: Multiple-Tier Increasing Block
MWD: Metropolitan Water District
SMC: Short-Run Marginal Cost
SWP: State Water Project
TAC: Technical Advisory Committee
TVC: Total Variable Cost

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returns to scale, marginal cost pricing leads to (revenue) deficits" (Renzetti, 2000).

For the case of natural monopoly with LMC less than LAC, the solution to revenue sufficiency is two-part pricing (Coase, 1946), with a "volumetric" (or "commodity") charge equal to marginal cost and a "customer charge" (or "connection fee") to collect sufficient revenue, assuming meters exist that measure each customer's water use. The numerical example presented here reverses this result; for a natural monopoly with LMC greater than system average cost, the two-part pricing solution sets the commodity charge equal to LMC and includes a rebate (or negative customer charge) to avoid monopoly profit. As an alternative to a negative customer charge, Los Angeles (LA) implemented a two-tier rate design with an initial lower tier price up to a threshold quantity of water consumed, and a higher LMC second-tier price for consumption above the threshold quantity, as illustrated in the numerical example.

Two problems with an increasing, two-tier rate design (or with a high LMC commodity charge and a rebate) are revenue instability and political infeasibility. The cost structure that determines the revenue requirement includes large sunk costs and low variable costs. With a high commodity charge given by the second-tier price, variation in demand causes revenues to vary out of sync with the revenue requirement and may necessitate repeated, time-consuming, politically difficult, and costly rate hearings in order for the utility to meet the revenue requirement. This article presents a solution to revenue stability adopted by LA by regularly adjusting the initial tier price to maintain sufficient revenue.

Rate reform that switches from a lower to a higher LMC commodity charge redistributes consumer surplus from large water consumers to small water consumers and may not be politically feasible. The concept of political feasibility is formally defined in Hall (2009). Political feasibility in some urban areas and developing countries entails special consideration for low-income consumers and in other circumstances simply reflects the political power of competing interests. In the case of LA, rates were modified by creating multiple, homogeneous subgroups of residential customer classes with different thresholds, and adjusting each threshold amount between the two-tier prices so that each subgroup on average paid an amount similar to other subgroups for water, a solution considered equitable by enough members of the city council to approve the rate design. The numerical example illustrates such politically feasible water rates.

Climate change is expected to result in prolonged droughts occurring worldwide (Cook et al., 2004; Gleick, 1990; Sohn, 2007). Water transport, reclamation, treatment, and desalination require tremendous quantities of electricity, with associated external costs. Climate change and externalities from water consumption have profound implications for the calculation of LMC and the importance of economic efficiency relative to the other objectives of water rate design.

Compared to the rate design in LA, water rate designs with increasing multiple-tiered prices are more common where water is scarce, such as the western United States. Alternative designs are compared and contrasted with respect to the policy objectives of rate design. The numerical example dispels common misconceptions about increasing block rate design and marginal cost rates, addresses "problems and limitations" of increasing block rate design (Boland and Whittington, 2000), and shows the political feasibility of achieving rate reform based on a two-tiered increasing block design with thresholds that vary among subgroups. This analysis highlights substantial potential to better meet policy objectives by implementing the LA rate design and identifies worldwide examples where this model rate design is applicable.

Section II presents the rate reform implemented in LA. Section III introduces embedded cost (EC) rate design, short-run marginal cost (SMC) rate design, and LMC rate design. The numerical example in Section III illustrates why LMC exceeds LAC in the case of natural monopoly and illustrates that economic surplus is greater with LMC rates compared to either SMC or EC rates. Section IV presents the reasons utility management typically opposes LMC rates, the arguments management and economic consultants make against LMC rates, and presents solutions to the problems facing management that the LA rate design achieves. Section IV also presents arguments for SMC versus LMC rates and considers those arguments in the context of conservation investments, droughts, increasing costs of water storage, and climate change. Section V summarizes how LMC rate design can be modified to become politically feasible and be perceived as fair. Section VI evaluates the LA rate design relative to alternatives based on the policy criteria—the objectives of rate design enumerated above and by Boland and Whittington (2000). Section VII concludes with examples where the features of the LA water rates have and can be more generally applied.

II. LA RATE REFORM

At the end of the droughts of 1976–1977 and 1987–1992,[1] both Tucson and LA attempted rate reform, switching to LMC rate designs, but these reforms proved politically infeasible.[2] In LA, after the 6-yr drought of 1987–1992, the mayor appointed the 1991–1992 Mayor's Blue Ribbon Committee for Water Rates. The 1991–1992 committee recommended a rate design that achieved revenue stability and revenue sufficiency and set the second-tier price equal to LMC, varying by season (Table 1), adopted by the city council with some modifications (bottom of Table 2). All residential customers paid the same lower, initial tier price up to a citywide threshold amount and paid the second, higher tier price equal to LMC for amounts exceeding the threshold, illustrated in Figure 1 with threshold T_2.

The 1991–1992 committee separated revenue stability and sufficiency from economic efficiency in the rate design. To meet the revenue constraint, the committee recommended regular adjustments to the initial tier price (holding the threshold constant). During normal rainfall years, the higher second-tier price equaled LMC to achieve economic efficiency.

During declared shortages, the rate ordinance included automatic increases for the second-tier price and automatic reductions in the threshold, with the magnitude of these adjustments specific to severity of the shortage, given in Table 1 for the 1991–1992 rate design. The second-tier price is based on the price elasticity of demand and set to equate the quantity demanded equal to the water available, given the size of the declared shortage (Table 1). The lower, initial tier price is regularly adjusted to meet the revenue target. The result is a rate design that meets the efficiency, revenue sufficiency, and revenue stability criteria during shortages.

After the drought ended, a new mayor appointed the 1993–1994 Mayor's Blue Ribbon Committee on Water Rates. The 1993–1994 committee modified the rate design to be politically feasible after the drought (top of Table 2 and middle column of Table 4) and forwarded their recommendations to the Department of Water and Power (DWP) Board of Utilities. The Board modified the thresholds in the rate design (Table 3). The city council further modified the thresholds (column 3 of Table 4) and passed an ordinance[3] in 1995 implementing the recommendations.

The 1993–1994 committee's innovations separated political feasibility from economic efficiency, and from revenue sufficiency, in both the rate design and the rate reform process. To achieve political feasibility, the rate design created homogeneous subgroups, each with a different threshold amount (Table 2), although all subgroups faced the identical initial and second-tier prices. The rate reform process included a Technical Advisory Committee (TAC)[4] that recommended the LMC second-tier price; utility management calculated annual adjustments for revenue stability; the DWP Board of Commissioners recommended additional subgroups and adjusted thresholds (Table 3), and the city council recommended even more subgroups and made further adjustments to the threshold amounts (Table 4) prior to approval of the rate ordinance.

The LA rate reform illustrates political feasibility; innovative features of the rate *design* and rate reform *process* separate the efficiency gains from the political resolution of how much winners compensate losers. The rate design can achieve economic efficiency and revenue sufficiency. With multiple subgroups, each with a different threshold, the rate reform process makes rate reform politically feasible. The 1995 ordinance has been amended five times since, adjusting the second-tier price up and the first-tier price down; subgroups and thresholds have not changed since 1995.

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[1] The drought began in the fall, 1986, and the "rainfall year" that measures precipitation crosses two calendar years.

[2] The details in Tucson are recounted by Martin et al. (1984) and in LA by Hall (2009).

[3] Ordinance no. 170435.

[4] Economists on the TAC to the 1991–1992 Blue Ribbon Committee (BRC) represented the BRC, the consultants to the BRC, National Economic Research Associates whom the DWP management retained, and two University of California, Berkeley, professors. The author served on the 1991–1992 and 1993–1994 BRCs and the TAC.

TABLE 1
Normal and Shortage Year Water Rates Recommended by Mayor's 1991–1992 BRC

				Higher Tier Price			
	Lower Tier Price		**1991–1992 Threshold**	**Summer**		**Winter**	
Normal year	1991–1992	2009	BU = 748 gallons	1991–1992	2009*	1991–1992	2009*
Residential							
Single family	$1.71	$1.32	21 BU/mo	$2.92	$3.28	$2.27	$2.69
Multifamily	$1.71	$1.33	125% of winter average	$2.92	$3.28	$1.71	$1.33
Commercial/industrial	$1.78	$1.42	125% of winter average	$2.92	$3.28	$1.78	$1.42
10% Shortage							
Residential							
Single family	$1.71	$1.32	19 BU/mo	$3.70	$3.94	$3.70	$3.94
Multifamily	$1.71	$1.33	115% of winter average	$3.70	$3.94	$3.70	$3.94
Commercial/industrial	$1.78	$1.42	115% of winter average	$3.70	$3.94	$3.70	$3.94
15% Shortage							
Residential							
Single family	$1.71	$1.32	18 BU/mo	$4.44	$4.73	$4.44	$4.73
Multifamily	$1.71	$1.33	115% of winter average	$4.44	$4.73	$4.44	$4.73
Commercial/industrial	$1.78	$1.42	115% of winter average	$4.44	$4.73	$4.44	$4.73
20% Shortage							
Residential							
Single family	$1.71	$1.32	17 BU/mo	$5.18	$5.52	$5.18	$5.52
Multifamily	$1.71	$1.33	110% of winter average	$5.18	$5.52	$5.18	$5.52
Commercial/industrial	$1.78	$1.42	110% of winter average	$5.18	$5.52	$5.18	$5.52
25% Shortage							
Residential							
Single family	$1.71	$1.32	16 BU/mo	$6.05	$6.44	$6.05	$6.44
Multifamily	$1.71	$1.33	110% of winter average	$6.05	$6.44	$6.05	$6.44
Commercial/industrial	$1.78	$1.42	110% of winter average	$6.05	$6.44	$6.05	$6.44

Source: Mayor's Blue Ribbon Committee on Water Rates (1992) and Ordinance no. 170435 as amended in 1997, 2000, 2004, 2006, and 2008.

*This rate is annually adjusted upward as specified in the ordinance.

The revenue adjustment has also been maintained in the 2008 ordinance. The ordinance specifies changes to the two-tier prices for 2008 and 2009, and the 2009 rates are provided in Table 1.

III. EC, SMC, AND LMC WITH NUMERICAL EXAMPLE

This section introduces the differences between marginal and EC rate designs. A simple numerical example, with LMC and SMC similar to those in LA, demonstrates that LMC rates are economically efficient and EC and SMC rates are inefficient.

Joskow (1976) presents theoretical reasons why the LMC might be higher than the LAC for a natural monopoly based on the distinction between the costs of the actual versus the optimal system. If the existing water system was scrapped, and a completely new water delivery system was designed and built from scratch, ex ante the LAC curve would be continuous and falling. The continuity comes from the ability to alter all parts of the system design. The economies of scale result from aspects of water supply and delivery that have the characteristics of a natural monopoly.[5] But scrapping the existing system would be wasteful, making irrelevant the theoretical, continuous, and declining LAC of a brand new system.

LMC is typically higher than historical average cost (HAC).[6] The American Water Works Association (2000) gives these reasons:

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[5] For example, the relationship between the area of a circle and the circumference means that the quantity delivered increases with the square of the radius, while the cost of a water pipeline increases by a factor of 2.

[6] HAC is an accounting concept related to sunk cost, whereas LAC is prospective.

TABLE 2

1993–1994 Mayor's BRC, Recommended Temperature, and Lot Size Thresholds

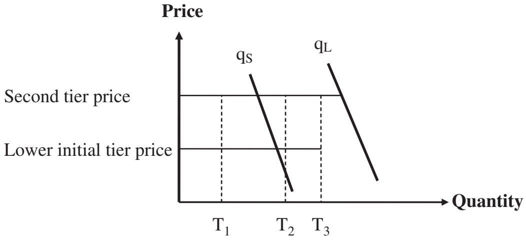
Lot Size (square feet)	Summer Average Daily High (°C)	Number of BU (BU = 748 gallons) Charged at Low Initial Tier Price	
		Winter	Summer
<7,500	<75	13	16
	75–85	13	17
	>85	13	17
7,500–10,999	<75	16	23
	75–85	16	25
	>85	16	26
11,000–17,499	<75	23	36
	75–85	24	39
	>85	24	40
>17,499	<75	29	45
	75–85	30	48
	>85	30	49
1991–1992 City Council Approved Rate Design Threshold			
All lots	All temperatures	22	28

Source: Mayor's Blue Ribbon Committee on Water Rates (1994).

"During the last twenty years of the twentieth century, the cost of supplying potable water increased significantly. This rapid increase can be attributed to a number of factors, including the passage and implementation of the U.S. Safe Drinking Water Act, the need to develop more remote and expensive water supplies, the need to replace aging infrastructure, and rapid economic development in some areas." West of the Mississippi River, LMC is greater than the HAC for additional reasons. The Ogallala aquifer, the largest source of glacial water in the United States, running from South Dakota to West Texas on the east side of the Rocky Mountains, has been mined, lowering the water table and increasing pumping costs (Reisner, 1993). West of the Rocky Mountains, a recent startling realization is that the stream flow of the Colorado River averaged over the past 500 yr is about 14 million acre-feet (MAF) at Lee's Ferry, not the 17.5 MAF on which the Colorado River Compact is based. During the current 10-yr drought that began in 1999, stream flow has averaged 5.4 MAF (2001–2003), one-half of the flow during the great Dust Bowl years (United States Geological Survey, 2004), an expected condition predicted to occur as a result of global warming (Gleick, 1990; United States Geological Survey, 1997). Also, dams are "wasting assets," slowly filling with sediment (Reisner, 1993, pp. 473–4) that inevitably reduces storage capacity. A consequence of the political pork barrel process is that we have already dammed virtually every feasible site, whether or not it was worthwhile, so that incremental sources of water are water reclamation projects, not untapped rivers. Water diversions between water basins can damage human health,[7] harm local economies,[8] extinguish fisheries and threaten ecosystems,[9] and damage the environment (Green, 2007). Courts have ordered reductions in water diversions and costly mitigation projects, internalizing some externalities

FIGURE 1

Separate Thresholds for Small and Large Customers



Description: The consumer pays the lower initial tier price for quantity up to the threshold, T_i, and pays the second-tier price (equal to LMC) for quantity greater than the threshold. The figure shows three alternative thresholds and two types of customers—small consumers and large consumers. If both customers face the same threshold, T_2, only the large customer pays the LMC and has an incentive to consume water and invest in water conservation efficiently. If the small customer faces threshold T_1 and the large customer faces threshold T_3, both customers have incentives to behave efficiently.

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[7] Under the Clean Air Act, LA DWP had to design and build mitigation projects to control windblown dust caused by diversion of water from Owens Valley to LA.

[8] Reisner (1993) describes the colorful struggle between LA and Owens Valley in the 1920s, and the governor of Arizona ordering a militia unit with machine guns to stop the construction by the Bureau of Reclamation of Parker dam on the Colorado River in the late 1930s. Current examples include a lawsuit filed by the Imperial County Board of Supervisors because of diversion of water from the Imperial Irrigation District to San Diego.

[9] Diversions of water flowing into Mono Lake threatened the ecosystem of the lake and exterminated fisheries in riverbeds below the dams, resulting in lawsuits against DWP based on Fish and Game code and the Public Trust doctrine (Wegge, Hanemann, and Loomis, 1996).

TABLE 3
Board of Commissioners Recommended Temperature and Lot Size Thresholds

Lot Size (square feet)	Summer Average Daily High (°C)	Number of BU Charged at Lower Initial Tier Price	
		Winter	Summer
<7,500	<75	13	16
	75–85	14	18
	>85	14	19
7,500–10,999	<75	16	23
	75–85	17	26
	>85	17	27
11,000–17,499	<75	24	36
	75–85	25	40
	>85	25	42
17,500–43,559	<75	28	45
	75–85	29	51
	>85	29	53
>1 acre	<75	36	55
	75–85	38	62
	>85	38	65
1991–1992 Rate Design Threshold			
All lots	All temperatures	22	28

Source: Ordinance no. 170435 as amended in 1997, 2000, 2004, 2006, and 2008.

Notes: A BU equals 748 gallons or 100 cubic feet. One AF equals 435 BU. During shortages, the threshold is reduced by the percentage of the declared shortage.

TABLE 4
Monthly Household Size BU Augmentation for Lower Initial Tier

Household Size	Mayor's BRC Recommendation	Ordinance Passed by City Council
6 or less	0	0
7	2	2
8	4	4*
9	5.5	6
10	7	7
11	8	8
12	9	9
13 or more	10	10

Source: Mayor's Blue Ribbon Committee on Water Rates (1994) and Ordinance no. 170435 as amended in 1997, 2000, 2004, 2006, and 2008.

Note: A BU equals 748 gallons or 100 cubic feet. One AF equals 435 BU.

*Automatic for 24 ZIP codes.

and thereby increasing the private marginal cost of water to the utility. Finally, as externalities from electricity generation are internalized,[10] the costs to the utility of pumping groundwater, transporting water, reclaiming, treating, and desalinating water will continue to rise in the future.

Many economists and others confuse HAC with LAC. HAC is the per-unit operating cost plus the per-unit sunk cost of capital, the latter measured by accounting principles. The *theoretical* LAC of supplying water is the per-unit cost of building and operating a new system, given today's factor input prices and technology. The *actual* LAC is discontinuous; actual LAC ignores sunk costs of the existing system and is based on the prospective costs of additions to the system. For systems built over decades (and with considerable subsidies), the HAC is effectively unrelated to actual LAC. This is true for most water utilities in dry areas throughout the world.

The LMC calculations were based on the average incremental cost approach[11] (Hirshleifer, DeHaven, and Milliman, 1960). For LA, the HAC was calculated at $1.67/billing unit (BU)[12] or $726/AF (Hall, 1996, p. 91), and LMC was calculated at approximately 1.5 times larger (Table 1, higher, second-tier price) than HAC. On the other hand, SMC is likely to be substantially lower than the HAC for utilities expanding capacity to meet growing populations. In LA, SMC is approximately half the HAC. From initial calculations (Hall, 1996, pp. 86–87), SMC = $0.64/BU and $0.91/BU or $278/AF and $396/AF in the winter and summer, respectively. In later calculations, the SMC was estimated at $0.25/BU higher in both periods (Hall and Hanemann, 1996, p. 108).

A. Numerical Example

Tables 5–8 present a simplified numerical example of a utility with growing demand served by discrete additions to capacity, with SMC and LMC that are close to those of LA. The initial quantity demanded equals 78 units at a price (commodity charge) of $1/BU (and with a fixed charge equal to the historic fixed cost of $39 divided by the number of customers), and demand is expected to grow from Q_0

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[10] Assembly Bill 32 requires California utilities to meet a renewable resource portfolio standard.

[11] There are other approaches and various issues associated with them (Carriker, 1998; Hall, 1996).

[12] A BU equals 748 gallons or 100 cubic feet. One acre-foot (AF) equals 435 BU.

TABLE 5
Numerical Example—Demand Growth and Incremental Cost

Original Quantity Demanded before Growth in Demand	New Quantity Demanded by Small and Large Customers	Historical H_2O Supply System	Incremental Cost of New Water Projects
$Q = 78$	$q_S = 40 - 2P_C$	$Q_0 \leq 78$	$Q_1 \leq 24$
	$q_L = 80 - 4P_C$	$HFC_0 = \$39$	$CC_1 = \$48$
	$Q = q_S + q_L$	$AVC_0 =$ \$1/unit	$AVC_1 =$ \$1/unit
			$Q_2 \leq 12$
			$CC_2 = \$48$
			$AVC_2 =$ \$1/unit
			$Q_3 \leq 12$
			$CC_3 = \$96$
			$AVC_3 =$ \$/unit

Notations: q_S, small customer; q_L, large customer; Q, total quantity demanded; P_C, commodity charge; Q_0, system capacity; HFC_0, historic fixed costs; AVC, average variable cost; CC, capital costs (rental rate).

to Q_1 in Figure 2. The utility has two customers, one large (L) and one small (S), with anticipated demand, $Q_1 = q_S + q_L$, depending on the commodity price, P_C:

$$q_S = 40 - 2P_C \tag{1a}$$

$$q_L = 80 - 4P_C. \tag{1b}$$

TABLE 6
Costs and Revenue Requirements

	Output	AVC	TVC	HFC or CC	Total Cost	Required Revenue
Normal rainfall year						
Original	78	1	78	39	117	
Project 1	24	1	24	48	72	
Subtotal	102	1	102	87	189	189
Project 2	12	1	12	48	60	
Total	114	1	114	135	249	249
Drought						
Original	66	1	66	39	105	
Project 1	24	1	24	48	72	
Subtotal	90	1	90	87	177	177
Project 2	12	1	12	48	60	
Project 3	12	1	12	96	108	
Total	114	1	114	231	345	345

TABLE 7
Tariff Designs and Revenue for Normal Rainfall and Drought Years

	LMC Rate Design	EC Rate Design	LMC Rate Design	EC Rate Design
	Normal Year		Drought	
Revenue and revenue shortage from a single-part (commodity charge) tariff				
P_C	3	1	5	1
q_S	34	38	30	38
q_L	68	76	60	76
Q	102	114	90	114
$P_C \times q_S$	102	38	150	38
$P_C \times q_L$	204	76	300	76
$P_C \times Q$	306	114	450	114
RR	189	249	177	345
RS	−117	135	−273	231
Two-part tariff to equate revenue with costs				
FC	−58.5	67.5	−136.5	115.5
Commodity (variable) charge	3	1	5	1

Notations: RR, required revenue; RS, revenue shortage; FC, fixed charge; CVC, commodity (variable) charge.

The historical water supply system has a maximum system capacity of 78 units of water during normal years. Total fixed cost equals \$39, average variable cost (AVC) equals \$1/unit (line segment *AB* in Figure 2), and total variable cost (TVC) equals \$78 to operate the system at capacity.

Figure 2 presents the discontinuous, LAC for the existing system, given by the segmented curves *AB*, *CD*, and *EF*:

$$\text{LAC} = 1 \quad \text{if } 0 < Q \leq 78, \text{line } AB \tag{2a}$$

$$\begin{gathered}\text{LAC} = [48/(Q - 78)] + 1 \\ \text{if } 78 < Q \leq 102, \text{curve } CD\end{gathered} \tag{2b}$$

$$\begin{gathered}\text{LAC} = [48/(Q - 102)] + 1 \\ \text{if } 102 < Q \leq 114, \text{curve } EF.\end{gathered} \tag{2c}$$

LAC equals \$1 between 0 and 78 units of output because previous capital costs are sunk costs. The prospective list of water projects is given in increasing order of cost in Table 5. For output greater than the capacity of the

TABLE 8
Economic and Consumer Surplus

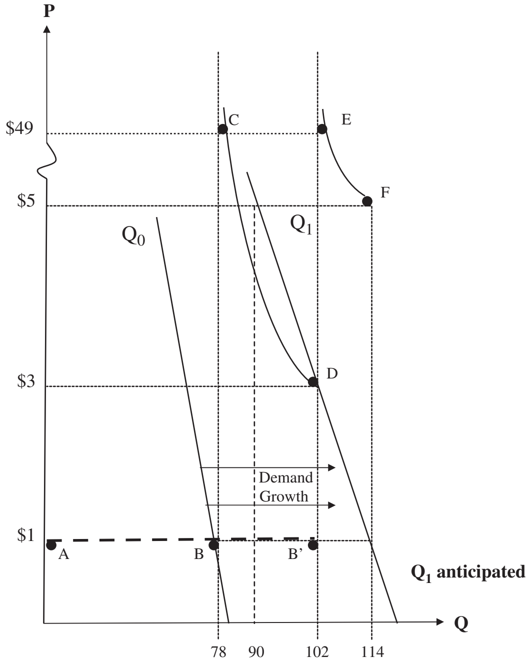
	LMC Rate Design	EC Rate Design	LMC Rate Design	EC Rate Design
	Normal Year		Drought	
Economic surplus	1023	987	987	891
Consumer surplus				
CSsmall	347.5	293.5	361.5	245.5
CSlarge	636.5	654.5	586.5	606.5
CStotal	984	948	948	852

Change in Consumer Surplus, Switch from EC to LMC Rate Design

	Normal Rainfall Year	Drought
ΔCSsmall	54	116
ΔCSlarge	−18	−20
ΔCStotal	36	96

existing system, the ex ante LAC is discontinuous at output equal to 78 units, and LAC is defined by the capital cost of Project 1 plus AVC for output in between 78 and 102 units, the additional capacity provided by Project 1. Ex post, after building Project 1, but ex ante to Project 2, LAC is given by \$1 for output between 0 and 102 units (*A* to *B′* in Figure 2)—the new system capacity. This assumes that capital costs for Project 1 are sunk costs after the project is built. (For output beyond 102 units, LAC is given by the capital costs of Project 2 plus AVC. In Figure 2, the upper left portions of curves *CD* and *EF* asymptotically approach vertical lines at $Q = 78$ and 102, respectively. At outputs 79 and 103, curves *CD* and *EF* equal \$49/unit.)

FIGURE 2
Existing System LRAC



B. EC and SMC Rate Designs

A simple EC rate design sets the commodity charge equal to AVC and sets the fixed (customer) charge so as to cover fixed historic costs. In this numerical example, AVC is constant and equal to SMC, so for this example, an SMC rate design is identical to a simplified EC rate design.

Table 6 summarizes the costs and revenue requirements for water systems of different capacities. If the commodity charge, P_C, were set equal to SMC = AVC = \$1/unit, the new quantity demanded would equal 114 units (see Equations 1a and 1b). During a normal rainfall year, both projects would have to be built for the regulated monopoly to meet its obligation to serve. With an SMC single-part tariff (commodity charge), Table 7 shows a revenue shortage of \$135 during a normal rainfall year and gives the two-part tariff to equate total revenue with required revenue. The fixed charge, *f*, equals \$67.50 per customer and the commodity charge, P_C, equals the AVC, \$1/unit; and total revenue equals:

$$\text{(3)} \qquad \mathrm{TR} = P_C(q_S + q_L) + fN = \$249,$$

where *N* is the number of customers, in this example equal to two. Required revenue equals:

$$\text{(4)} \qquad \begin{aligned} \mathrm{RR} &= \mathrm{AVC} \times Q + \mathrm{HFC}_0 \\ &+ \mathrm{CC}_1 + \mathrm{CC}_2 = \$249, \end{aligned}$$

where AVC is average variable cost, $Q = q_S + q_L$, HFC_0 is remaining historic fixed cost, and CC_1 and CC_2 are the rental capital costs of Water Projects 1 and 2, respectively (Table 6).

The alternative to building both Projects 1 and 2 is given by an LMC rate design.

Operated at capacity, 24 units, Project 1 has a total variable cost of $24, for an incremental cost of $3/unit. With an single-part tariff commodity charge set equal to $3/unit—slightly less than the actual second-tier price in LA set for July 1, 2009 (Table 1)—the total quantity demanded, 102, just equals system capacity with Project 1 built. Table 7 shows that excess revenue would equal $117. A two-part tariff could rebate to each of the two customers $58.50.

C. Inefficiency of SMC Rate Design and EC Rate Design

Table 8 presents the choice between keeping the commodity charge equal to $1/unit at the SMC[13] versus raising the commodity charge to $3/unit, the LMC. For SMC rate design, total benefits equal the area under the demand curve from 0 to 114 units, and total costs equal the rectangle under the AVC curve plus the capital costs of the two projects. The net economic surplus equals $987. Alternatively, if the commodity charge is set equal to $3, we will only have to build Water Project 1. Economic surplus is then greater if the rate design is based on LMC ($1,023) rather than SMC ($987). Table 8 also presents the consumer surplus portion of the economic surplus, which differs from the economic surplus by the sunk cost of the original system.

IV. THE ROLE OF WATER UTILITY MANAGERS AND REVENUE SUFFICIENCY

Revenue sufficiency is an objective[14] of rate design (American Water Works Association, 1991), an objective arguably met by EC rate design but not LMC rate design. If a large portion of total revenue is collected from fixed charges, so that a small portion of revenue depends on commodity charges, then variation in quantity sold does not cause significant variation in net revenue, and the rate design achieves "revenue sufficiency." EC rate design achieves this objective during normal years. When LMC is higher than HAC, an LMC rate design creates excess revenue, which can be avoided by an increasing block structure that equates total revenue to total cost. An LMC increasing block design sets the second-tier price higher (equal to LMC), but then any shift in demand results in a substantial change in revenue (relative to a declining block—or flat—rate design), necessitating more frequent rate approval hearings. Frequent rate approval hearings are time consuming and expensive and reopen the political issues of rising costs and cross-subsidies among subgroups of customers. Elected representatives can use the rate approval process as an opportunity to attack utility management, and managers face negative press coverage. Management suffers adverse job effects, ranging from accounting and management audits to lower salaries and loss of nonpecuniary compensation. Municipal utility managers do not desire LMC rate designs if it means that they will have to request rate changes with greater frequency than with EC rate design. The LA LMC rate design achieves revenue sufficiency during both droughts and normal rainfall years, solves the problem of frequent rate hearings, but still has rate hearings and regulatory oversight with regular frequency.

The TAC to the 1991–1992 BRC recommended that the LMC rate ordinance includes a provision creating a revenue-stability fund from which revenues could be drawn to meet costs as the quantity demanded fluctuates. The TAC recommended that the initial tier price (not the threshold) be adjusted at regular intervals so that the fund meets a target, avoiding the need to repeatedly return to the City Council for changes in the rate ordinance. A fund is not necessary, could be misused, and the end result did not include one. It is sufficient to set up a revenue target for each interval and adjust the initial tier price upward if the target is not met and downward if the target is exceeded. The rate ordinance constrains the size of the adjustment to a limit beyond which there is a time period for review by the City Council. If the City Council does not vote to review it, the adjustment goes into effect. This rate adjustment process in the proposed rate reform made the marginal cost rate design politically palatable from the DWP management's perspective, avoided an increase in the frequency of hearings that an LMC rate design might cause, and the utility managers agreed to not oppose an LMC design.

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[13] This is actually the short-run inframarginal cost. See the discussion that follows in the subsection titled "The Argument for Short-run Marginal Cost."

[14] Although the American Water Works Association refers to "Revenue Stability," more accurately, zero net revenue is the objective—sometimes referred to as "Revenue Sufficiency."

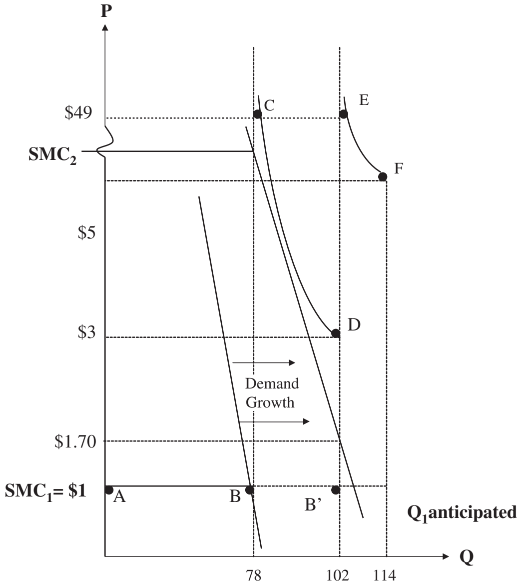
Over time, the revenue sufficiency achieved by an automatic adjustment could lead to the perverse result that LMC rates are not updated in a timely manner, although that did not happen in the case of LA. As LMC rises over time, without adjustments the second-tier price no longer achieves efficiency. After rate design hearings, LA adjusted the second-tier price to equal LMC as it shifted higher over time when the ordinance was amended in 1997, 2000, 2004, 2006, and 2008. The 2008 amendment includes annual adjustments to the second-tier price that account for internalization of external costs of water transfers.[15] A revenue-neutral change to the rate design can reset the second-tier price higher, equal to the LMC, reducing the initial tier price (Table 1), politically easier to achieve compared to rate requests with large revenue increases.

A. The Argument for SMC

The term "benign monopoly rates" here refers to an ideal invoked by economists: rates are set by an unregulated, benign monopolist, where the utility knows its cost structure, has the authority to set prices, and to instantaneously vary the prices; and one objective is to achieve economic efficiency by varying the commodity price to equal SMC and the other objective is to avoid collecting monopoly profit by setting (negative) fixed charges. A "rate design," by contrast, has at least some features fixed over time, with changes that require approval by a regulatory body in a rate approval process, with regulatory lag.

DWP's economic consultant argued in favor of SMC rate design over LMC. As the original demand curve in Figure 3 shifts toward the right, given system capacity at 78 units, the short-run opportunity cost is no longer the inframarginal cost ($1/BU) of producing the inframarginal (78th) unit, but rather, it is simply the foregone opportunity to consume. With demand growth, the opportunity cost is given by the willingness to pay—the price where the demand curve intersects the vertical short-run supply curve (line segment *BC*) at system capacity (78 units)—illustrated in the figure somewhere between $5/unit and $49/unit. When demand grows, once system capacity is reached, the unregulated, benign monopolist charges the SMC price that allocates the available supply (Mann, Saunders, and Warford, 1980). As demand continues to grow, the price increases toward point *C* until it becomes economical to build the first project; the price at which that occurs depends on the shape of the demand curve relative to the size of the additional capacity of the project. After construction is completed, the short-run marginal opportunity cost falls (perhaps all the way back to $1/unit or in the example as illustrated in Figure 3 to $1.70) depending on demand. As demand continues to grow beyond that shown in Figure 3, the price rises toward point *E* until Project 2 is built and then falls. The result is a fluctuating price with instantaneous adjustments made by the benign monopolist. This is the argument in favor of SMC rate design that the DWP economic consultants made to the TAC and was also made by the American Water Works Association (1991). This argument is a canard because in practice SMC rate design requires rate hearings with regulatory lag: as demand grows so that the market clearing price is higher than the cost of the last unit produced, the regulatory lag results in the commodity charge being based on the cost of the

FIGURE 3
SMC Benign Monopoly Rates



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[15] The Owens Valley Regulatory adjustment in the 2008 ordinance accounts for the cost of mitigation projects. See Footnotes 7–10 and the accompanying discussion.

inframarginal unit of supply, not based on the opportunity cost. SMC rate design cannot mimic prices determined by demand and cost because changes in the rate design require a rate approval process with regulatory lag.[16]

With EC rates, the political problem for retail water utility managers occurs during droughts that are severe enough to extend beyond the capacity of surface and groundwater storage of the wholesale utility. Solutions to severe droughts include wholesale water agencies building more surface water storage capacity and water desalination plants that are unused during normal years. Of course, these solutions are expensive in the extreme,[17] but they are exactly the solutions implemented by the Metropolitan Water District (MWD) of Southern California (Rodrigo, Blair, and Thomas, 1996), which wholesales water to 26 water agencies, including DWP. Additional water storage is under consideration by the State Water Project (SWP), itself a wholesaler to MWD. Some of the money to pay for SWP and MWD reservoir and system reliability more generally comes from fixed charges such as property taxes and general obligation bonds rather than revenue bonds. Economic consulting firms argue in favor of fixed charges and general obligation bonds based on the logic of SMC benign monopoly rates presented above. The canard goes like this: storage is in excess capacity during normal rainfall years, built to serve during long-term droughts (or major earthquakes); excess storage capacity is a slack variable during normal rainfall years, and the theoretical value of a slack variable is 0; so it is inefficient to include the cost of storage in the wholesale price during normal years, and this justifies subsidies from the general taxpayer to keep wholesale rates lower. In theory, SMC benign monopoly rates would pay for the entire investment in system storage and reliability by charging extremely high prices during droughts and earthquakes. But it is not politically feasible to charge extraordinarily high prices to completely finance massive investments needed solely during catastrophes. With EC or SMC rate design, the reality is that the wholesale water agency builds economically inefficient excess capacity, and the subsidized portion of the cost of reservoirs built by wholesale agencies is not reflected in the wholesale price, nor in the retail price, so that retail water agencies lack incentives to develop local resources and consumers lack incentives to invest in water-efficient landscaping and appliances.

B. Conservation Investments, Benign Monopoly Rates, and SMC Rate Design

When consumers have investment choices that conserve water, there is another reason why both SMC rate design and SMC benign monopoly rates are inefficient. The opportunity cost is no longer just the cost of providing more water, but it includes the cost of water conservation investments by the consumer. The argument for the unregulated, benign monopoly assumes the monopoly knows the cost of supply and has the ability to rapidly change price in order to ration supply at system capacity. In order to achieve efficiency through pricing, the benign monopolist would also have to know the customer's water efficiency investment opportunities and the *a priori* behavior of its customers in response to price changes. In order to provide the incentive to consumers to make the optimal long-term investments in water conservation, water rates based on the LMC of supply provide the appropriate price signal so that consumers have an incentive to invest in conservation when it is cheaper than the utility investing in additional supply.

The problem with benign monopoly rates is that the benign monopolist presents fluctuating prices to the customers, giving the signal to potential water conservation investors that water supply is uncertain (Mann, Saunders, and Warford, 1980); yet, in the numerical example that generates this price variability, there is no supply uncertainty. Advocates of SMC rates argue that with perfect foresight, consumers would avoid conservation investments that cost, per unit, greater than \$3/unit, even if the SMC price rose to \$49 (Figure 3). The benign monopoly rates argument ignores the role of prices as a means of signaling scarcity between producers and consumers, and assumes instead that the cost of information about scarcity is zero, ignoring the role of markets.

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[16] There is an exception. For temporary shortages, an SMC rate design, as implemented by LA in Table 1, is efficient; this is presented below.

[17] Less expensive solutions include conjunctive use of surface and groundwater with an increase in the amount of groundwater storage (Green, 2007).

The result of SMC rate design is inefficient underinvestment in water conservation and overinvestment in water supply. In the numerical example, let the anticipated demand curve, Q_1 in Figure 2, be anticipated demand in the absence of conservation. Assume that both customers have water conservation investment opportunities with capital rental rates of \$2/unit. Assume these are lumpy investments where the large customer's investment saves 16 units, and the small customer's investment saves 8 units of water. With SMC rate design, the commodity charge is equal to the inframarginal cost at \$1/unit. The conservation opportunities will be foregone and both water projects will be built. With LMC rate design, the conservation investments will take place, shifting demand to the left by 24 units:

$$q_S = 40 - 8 - 2P_C \tag{5a}$$

$$q_L = 80 - 16 - 4P_C. \tag{5b}$$

With a commodity charge equal to \$3/unit, both customers invest in conservation, total quantity demanded equals 78, and there is no need to build either water project. Since water and water conservation investments are perfect substitutes, consumer and economic surplus are calculated from the original anticipated demand curves, subtracting the cost of the conservation investment rather than the cost of building and operating Project 1. With 24 units of water provided at \$2/unit through conservation, instead of 24 units provided from Project 1 at \$3/unit, conservation saves \$24. Economic surplus with LMC rate design equals a total of \$1,047[18] relative to \$987 with SMC rate design. LMC rates, with easily understood billing formats and information about water conservation alternatives, will avoid losses in economic surplus. The policy alternative to LMC rate design is to provide customers with rebates for purchasing water-efficient appliances, a prevalent practice for water utilities in drier climates.

C. Droughts versus Drier Climate: Short-Run versus Long-Run Rate Design Revisited

The 1976–1977 drought in California, the worst recorded in the state's history, up to that date, was exceeded during the 1987–1992 drought.[19] For temporary shortages, in 1992, LA implemented a rate design that automatically increases the second-tier price, dependent on the amount of the declared shortage, to equate demand and supply (Table 1). The 2008 rate ordinance adjusts the threshold amount (Table 3) of water available at the lower initial tier price for each subgroup by an amount equal to the percentage of the declared shortage. The rate design also allows for adjustments to the initial tier price at regular intervals to meet the revenue constraint of zero net revenue. This is an example of a rate design with features that mimic pricing by a benign monopolist.

Consider a long-term drought that in the numerical example reduces the available supply from 78 to 66 units, shown in Table 6. In addition to Projects 1 and 2, a third project can provide additional water at a higher incremental cost shown in Table 5, with the variable cost remaining at \$1/unit. With EC rates, the quantity demanded grows the same as during normal rainfall years to 114 units, and all three units are built to meet demand. The commodity charge during a drought equals \$5/unit for the LMC design (Table 7); \$5 is the cost per unit of the second project, a project avoided by LMC pricing. In the example with LMC rates, the commodity charge is given by the incremental cost of the next (second) unit, the quantity demanded equals 90 units, and the utility needs to build the first unit, but not the second unit nor the third.

Since an LMC cost rate design is economically efficient relative to the EC rate design, there is a welfare loss from EC rates. In the example, the welfare loss equals \$36 during normal rainfall years and \$96 during a drought (Table 8). The higher welfare loss in a drought relative to normal rainfall years is a result of the increase in the incremental cost of additional water from the highest cost project built given EC rates but avoided with LMC rates.

Three sources of storage are surface water reservoirs, groundwater, and snow pack. Climate change reduces all three and brings

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[18] \$1,023 + \$24, see Table 8.

[19] The current 9-yr drought in the western United States is "unprecedented in some hydroclimatic records" extending back 1,200 yr (Cook et al., 2004); similarly for Australia (Sohn, 2007). During the Medieval Warm Period, for 400 yr from 900 to 1300 AD, the climate of the western United States was drier (Cook et al., 2004) with droughts lasting as long as 60 yr (Gertner, 2007).

climate instability—geographical variation in intensity and duration of rainfall and drought (Hall and Behl, 2006). A warmer climate diminishes snow pack storage because spring rainfall melts snow, causing spring floods during dry years. In order to control spring floods, we must then empty surface storage capacity even during dry years. Warmer climates increase evaporation from surface water storage facilities and increase transevaporation, leading to higher demand by plants. Drawdown from groundwater aquifers during long droughts can compact the structure of aquifers, irreversibly reducing their capacity.

Climate change is destroying storage capacity. Expensive, new surface water storage and water transfer projects are under consideration because of climate change in California, Arizona, and Colorado. Wholesale water agencies should charge retail water agencies for the entire cost of improvements, capacity additions, and environmental restoration rather than obtaining subsidies from the general taxpayer. Politically, the subsidies seem to prevail, and in this circumstance, LMC rate designs for retail water agencies should incorporate the cost of water projects' subsidies to wholesale water agencies to provide the correct incentive for efficient investment in water conservation by consumers.

V. VARIATION IN THE THRESHOLDS: EFFICIENCY, FAIRNESS, AND POLITICAL FEASIBILITY

The American Water Works Association (2000, p. 167) presents a drawback to increasing tiered rate design: only the largest users receive the price inherent in the high marginal cost rate. Boland and Whittington (2000) critique increasing block rates because "a large number of customers probably face different prices" not equal to marginal cost. As shown in Figure 1, if large and small customers face the same threshold, T_2, then only the large customer has an incentive to efficiently invest in conservation, and the small customer never faces the second-tier price. If the small customer has a threshold set at T_1 and the large customer has a threshold set at T_3, then both customers face the second-tier price. For an increasing two-tiered rate design based on LMC, setting different thresholds for each subgroup will increase the number of customers facing the efficient price incentive. If all customers face the same threshold, heterogeneity in demand guarantees that the rate design is inefficient for some small customers.

Greater efficiency is achieved by creating more homogeneous customer classes, and setting each threshold to increase the percentage of customers purchasing some amount of water at the second-tier price. In LA, the subgroups are divided by temperature zone, lot size, and family size, identified by postal ZIP code, so that the threshold varies geographically. The less than favorable review of marginal cost rate design by the American Water Works Association (2000) assumes that all customers face an identical citywide threshold, but the LA rate design solves this problem.

A second justification for variation in thresholds among customers is the perceived relative fairness it provides. The threshold amount can be set so that the average price paid for water is equal, or nearly so, for both large and small customers; this concept of fairness may also achieve political feasibility. A normative justification is that the amount defined by the threshold can be set equal to a "baseline" amount that meets basic human needs, an amount that "should" be available at an affordable price. Temperature zones and lot size can be used to determine landscaping "needs," and family size can determine "needs" for indoor use. These three variables—temperature zones, lot size, and family size—were and are used by LA to set the thresholds for the initial tier price and to determine the number of subgroups.

In the context of a mandatory drought reduction, the East Bay Municipal Utility District (EBMUD), California, is currently proposing[20] a \$2/BU additional commodity charge for amounts exceeding a 10% reduction from a baseline separately calculated for each individual household, averaging the household's use over the previous three years. Setting the threshold individually for each customer based on previous years' consumption is perceived as unfair, penalizing those who conserved in the previous three years of the drought and sapping the goodwill of the community to conserve water during droughts. Individual thresholds also have the perverse incentive to keep use high during normal rainfall years, delaying investment in

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[20] See http://www.ebmud.com/drought/drought_rates_and_allocations_faqs.htm.

water conservation that is economical during normal rainfall years to keep a high baseline and retain investments, thereby avoiding the penalty. The perceived unfairness and perverse incentives are avoided in the LA rate design that identifies homogeneous subgroups and sets the thresholds based on statistics for the subgroup rather than setting thresholds based on previous individual consumption decisions.

VI. ALTERNATIVE INCREASING BLOCK RATE DESIGNS

Tucson, Arizona,[21] currently has a four-tier increasing block rate design and is proposing adjustments to the prices. EBMUD is proposing a four-tier design, with fixed customer charges.[22] Hewitt (2000) reports that many cities in Latin America have increasing block rates, with between 3 and 13 tiers. Boland and Whittington (2000) review increasing block designs for cities in the Philippines, Bolivia, Singapore, Jakarta, Thailand, and Sri Lanka, five of which have four-tier prices and one of which has three-tier prices. They identify deficiencies of these designs, including (1) inefficiency, (2) political pressure to increase the size of the initial block threshold, (3) revenue insufficiency, (4) complexity of the design lacking transparency to consumers and difficulty of administration, and (5) resale to others without water connections. With respect to these deficiencies, this section compares multiple-tier increasing block (MIB) rates with the LA two-tier rate design that varies the threshold geographically and by family size.[23]

MIB rates provide efficient prices to fewer customers relative to LA rates as shown in Figure 1 and discussed above. MIB rates allocate consumer surplus between small and large water users by adding additional tiers (reducing efficiency), while LA rates achieve political feasibility by adding additional homogeneous subgroups (increasing efficiency). Both MIB and LA rates can achieve revenue sufficiency with regular adjustments. MIB rates are less transparent to customers, while a two-tier design is easier for customers to understand; both rate designs are complex to administer. MIB rates result in greater opportunity for arbitrage since more customers consume at prices that differ from each other, while LA rates result in a greater percentage of customers at the higher second-tier price, reducing the opportunity for arbitrage. Fixed customer charges added to increasing block rates diminish the incentive to conserve and consume efficiently. With respect to these six deficiencies of increasing block rate design, the LA rate design is a dominant policy relative to MIB rate design.

The LA rate design does not achieve efficient water use from every customer. Within subgroups, customers who consume less than the threshold do not receive the efficient price incentive. A single block design with a commodity charge equal to LMC and with a rebate unrelated to consumption could achieve more efficiency than the LA design and achieve zero net revenue. (If the rebate is related to consumption, then the rebate will influence consumption, and no longer achieve efficiency.) A rebate unrelated to consumption is not, however, politically feasible. The LA design allows for thresholds related to average use in a subgroup that shift the gains from increased efficiency among customers. The shift in gains achieves notions of fairness and balances the political power among subgroups. Rate designs can be and have been adjudicated, and an arbitrary rebate may not be legal. For example, the rebate could be larger than a customer's bill. Another example, a rebate could be devised that is based on income: low-income customers could receive large rebates and high-income customers receive small rebates; such a tax and income redistribution policy would likely exceed the discretionary authority legally permitted to a utility, a form of taxation without representation.

VII. CONCLUSIONS

For water, economists erroneously assume that LMC is lower than LAC and erroneously estimate and use continuous cost functions as the basis for calculating the economic

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[21] See http://www.tucsonaz.gov/water/rates.htm.

[22] See http://www.ebmud.com/about_ebmud/financial_information/fy08_rates_charges_and_regs/default.htm. The rate design has three blocks plus a drought conservation surcharge and fixed charges dependent on the size of the pipe connection.

[23] Additions to the threshold for family size are granted to customers who fill out a form and sign under penalty of perjury similar to low-income rates for electricity and natural gas.

efficiency of water rates (e.g., Garcia and Reynaud, 2004). The numerical example in this article overturns this assumption (at least for drier regions) illustrates the distinction between LAC and HAC, and demonstrates that LMC rates are efficient, while SMC rates and EC rates are not.

Criteria for municipal utility water rate design include economic efficiency and efficient water conservation, zero economic profit, revenue sufficiency, and political feasibility. An increasing two-tier rate design with subgroup thresholds has four separate components: the second-tier price, the lower initial tier price, the number of subgroups, and the thresholds between the prices that vary among subgroups. During normal years or prolonged droughts, setting the second-tier price equal to the LMC achieves economic efficiency. Revenue sufficiency (zero net revenue) can be achieved with regular adjustments to the lower initial tier price. Allowing the threshold to vary across subgroups can achieve political feasibility if each subgroup is relatively homogeneous.

When droughts or other events cause short-term shortages, the rate *design* can include regular adjustments to the first-tier rate to meet the revenue target, automatic reductions to the thresholds proportional to the size of the shortage, and a second-tier price set to allocate the available supply and achieve efficiency.

For dramatic adjustments to the rate design, a rate reform *process* can separately allocate responsibilities; experts calculate the LMC, utility management calculates automatic adjustments to the first tier rate to meet the revenue constraint, and the rate approval body (elected officials and/or political appointees) refines the partitioning of the customers into subgroups and sets the threshold for each subgroup, shifting consumer surplus among subgroups to achieve political feasibility. Water rate reform is best achieved with a revenue-neutral revision to the rate design rather than during a rate hearing process with a request to increase revenue.

It is important for water utility management to regularly update the LMC. The calculation should include externalities caused by water transfers across watersheds, externalities from electricity generation to supply water, increasing treatment and water reclamation costs, and the cost of additional water storage under consideration by wholesale agencies. The second-tier price should be regularly adjusted to account for increases in electricity prices, purchased water prices, and rising treatment costs. These changes have occurred in LA during regular rate hearings.

The experience in LA presents a template for residential water rate reform in other cities. Although not discussed here, Table 1 also presents the LA rate reforms for municipal and industrial customers achieved at the same time as rate reform for residential customers. The lessons learned in LA are applicable to investor-owned water utilities as well. The concept of varying the threshold among subgroups of customers has just been approved for electric rates by the LA DWP. Southern California Gas Company, a subsidiary of Sempra, has a two-tier increasing block rate design and varies the threshold amount available at the initial tier price by season and among three climate zones. The two-tiered increasing block design with multiple, homogeneous subgroups each with a different threshold has opportunities for implementation worldwide where MIB designs are in use.

REFERENCES

American Water Works Association. *Financial Management: AWWA'S New Accounting Manual and Alternative Rates Manual*. Philadelphia: AWWA Annual Conference, 1991.

American Water Works Association. *Manual of Water Supply Practices: Principles of Water Rates, Fees, and Charges*, 5th edn. Denver, CO: AWWA Manual M1, 2000.

Boland, J. J., and D. Whittington. "The Political Economy of Water Tariff Design in Developing Countries: Increasing Block Tariffs Versus Uniform Price with Rebate," in *The Political Economy of Water Pricing Implementation*, edited by A. Dinar. New York: Oxford University Press, 2000, 215–35.

Carriker, G. L. "Book Review of Marginal Cost Rate Design and Wholesale Water Markets." *American Journal of Agricultural Economics*, 80, 1998, pp. 880–81.

Coase, R. "The Marginal Cost Controversy." *Economica*, 13, 1946, 169–82.

Cook, E. R., C. A. Woodhouse, C. M. Eakin, D. M. Meko, and D. W. Stahle. "Long-Term Aridity Changes in the Western United States." *Science*, 306, 2004, 1015–18.

Garcia, S., and A. Reynaud. "Estimating the Benefits of Efficient Water Pricing in France." *Resources and Energy Economics*, 26, 2004, 1–25.

Gertner, J. "The Perfect Drought: The Future is Drying Up," *New York Times Sunday Magazine*, 21 October 2007, sec. 6, p. 68.

Gleick, P. H., ed. “The Colorado River Basin and the Greenhouse Effect: Water Resources and Water Management,” in *Proceedings of a Workshop on the Implications of Climatic Change for the Colorado River Basin,* Denver, Colorado, May 17-18, 1990. Oakland, CA: The Pacific Institute, 1990, 72.

Green, D. *Managing Water: Avoiding Crisis in California*. Berkeley, CA: University of California Press, 2007.

Hall, D. C. “Calculating Marginal Cost for Water Rates,” in *Advances in the Economics of Environmental Resources: Marginal Cost Rate Design and Wholesale Water Markets*, Vol. 1, edited by D. C. Hall. Greenwich, CT: JAI Press, 1996, 77–94. http://www.csulb.edu/~dhall/.

———. “Prescriptive Public Choice with an Application to Residential Water Rate Reform.” *Contemporary Economic Policy*, 2009, doi: 10.1111/j.1465-7287.2009.00163.x

Hall, D. C., and R. J. Behl. “Integrating Economic Analysis and the Science of Climate Instability.” *Ecological Economics*, 57, 2006, 442–65.

Hall, D. C., and W. M. Hanemann. “Urban Water Rate Design based on Marginal Cost,” in *Advances in the Economics of Environmental Resources: Marginal Cost Rate Design and Wholesale Water Markets*, Vol. 1, edited by D. C. Hall. Greenwich, CT: JAI Press, 1996, 95–122. http://www.csulb.edu/~dhall/.

Hewitt, J. A. “An Investigation into the Reasons Why Water Utilities Choose Particular Residential Rate Structures,” in *The Political Economy of Water Pricing Implementation*, edited by A. Dinar. New York: Oxford University Press, 2000, pp. 259–77.

Hirshleifer, J., J. C. DeHaven, and J. W. Milliman. *Water Supply, Economics, Technology, and Policy*. Chicago: University of Chicago Press, 1960.

Joskow, P. L. “Contributions to the Theory of Marginal Cost Pricing.” *Bell Journal of Economics*, 7(1), 1976, 197–206.

Mann, P. C., R. J. Saunders, and J. J. Warford. “A Note on Capital Indivisibility, and the Definition of Marginal Cost.” *Water Resources Research*, 16, 1980, 602–04.

Martin, W. E., H. M. Ingram, N. K. Laney, and A. H. Griffin. *Saving Water in a Desert City*. Washington, DC: Resources for the Future, 1984.

Mayor’s Blue Ribbon Committee on Water Rates. *Assuring Our Future Water Supply: A Consensus Approach to Water Rates*. Los Angeles: Mayor’s Office, 1992.

———. *Recommendations for Revisions to Water Rates*. Los Angeles, 1994.

Reisner, M. *Cadillac Desert*. New York: Penguin Books, 1993.

Renzetti, S. “An Empirical Perspective on Water Pricing Reforms,” in *The Political Economy of Water Pricing Implementation*, edited by A. Dinar. New York: Oxford University Press, 2000, 123–140.

Rodrigo, D., T. A. Blair, and B. G. Thomas. “Integrated Resource Planning and Reliability Analysis: A Case Study of the Metropolitan Water District of Southern California,” in *Advances in the Economics of Environmental Resources: Marginal Cost Rate Design and Wholesale Water Markets*, Vol. 1, edited by D. C. Hall. Greenwich, CT: JAI Press, 1996, 49–73.

Sohn, E. “The Big Dry: Prolonged Drought Threatens Australia’s People, Wildlife, and Economy.” *Science News*, 172(17), 2007, 266.

United States Geological Survey. “Coping With Severe and Sustained Drought in the Southwest,” by Michael D. Dettinger, abstracted from the October special issue of the *American Water Resources Bulletin* (October 1995), 1997. Accessed March 13, 2009. http://geochange.er.usgs.gov/sw/changes/natural/codrought/.

———. “Climatic Fluctuations, Drought, and Flow in the Colorado River.” USGS Fact Sheet 3062-04, 2004. http://water.usgs.gov/pubs/fs/2004/3062/. Accessed March 13, 2009.

Wegge, T. C., W. M. Hanemann, and J. Loomis. “Comparing Benefits and Costs of Water Resource Allocation Policies for California’s Mono Basin,” in *Advances in the Economics of Environmental Resources: Marginal Cost Rate Design and Wholesale Water Markets*, Vol. 1, edited by D. C. Hall. Greenwich, CT: JAI Press, 1996, 11–30.