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

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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.

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

	Lower Tier Price		1991–1992 Threshold	Higher Tier Price			
				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:

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.

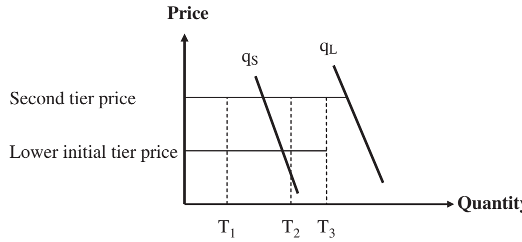
TABLE 2
1993–1994 Mayor's BRC, Recommended Temperature, and Lot Size Thresholds

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

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.

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

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

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:

(1a) $$q_S = 40 - 2P_C$$

(1b) $$q_L = 80 - 4P_C.$$

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:

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

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

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

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

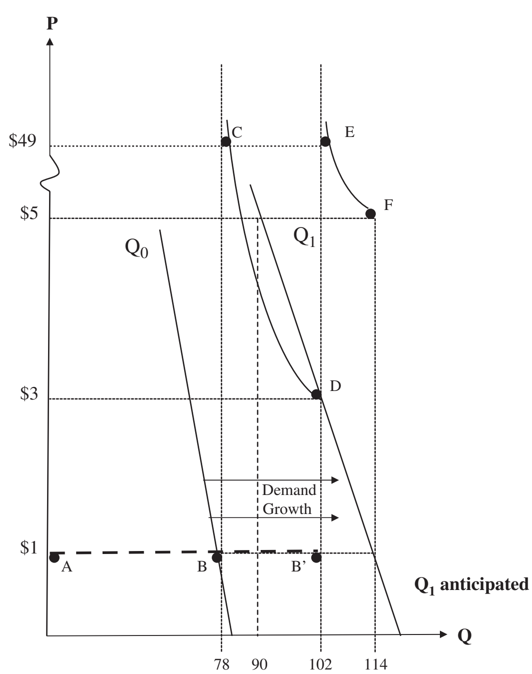
	LMC Rate Design	EC Rate Design	LMC Rate Design	EC Rate Design
	Normal Year		Drought	
Economic surplus	1023	987	987	891
Consumer surplus				
CSsmall	347.5	293.5	361.5	245.5
CSlarge	636.5	654.5	586.5	606.5
CStotal	984	948	948	852

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,

FIGURE 2
Existing System LRAC



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.)

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:

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

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

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

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.

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."

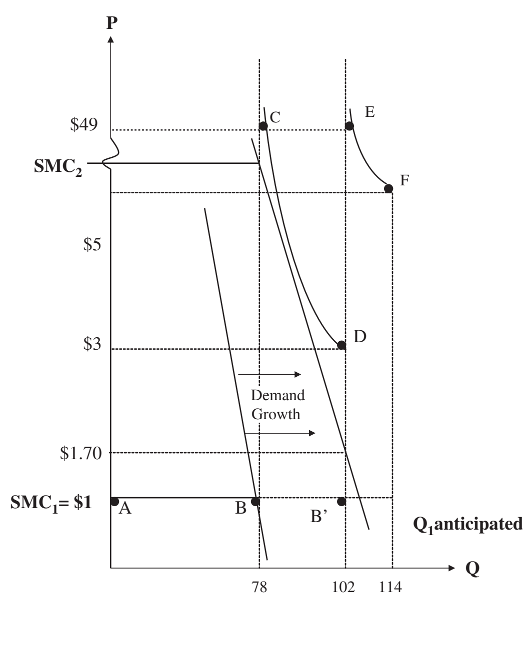
Over time, the revenue sufficiency achieved by an automatic adjustment could lead to the perverse result that LMC rates are not updated in a timely manner, although that did not happen in the case of LA. As LMC rises over time, without adjustments the second-tier price no longer achieves efficiency. 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



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.

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).

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.

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:

(5a) $$q_S = 40 - 8 - 2P_C$$

(5b) $$q_L = 80 - 16 - 4P_C.$$

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

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

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.

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.

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 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.

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PRESCRIPTIVE PUBLIC CHOICE: APPLICATION TO RESIDENTIAL WATER RATE REFORM

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Peltzman's model of price regulation predicts inefficient prices for regulated firms; based on a constraint giving the trade-off between economic profit and the regulated price, the price will be set between a competitive industry price and a monopoly price. This article generalizes the model for application to a wider class of trade-offs, including municipal utilities that are not legally permitted to make a profit. Extending Peltzman's idea of political support functions, this article defines political feasibility relative to economic efficiency. A Pareto superior change with compensation is sufficient but not necessary for political feasibility; the Kaldor-Hicks criterion is neither necessary nor sufficient for political feasibility. The generalization of Peltzman's model of public choice and the concept of political feasibility together explain why Tucson in 1976 and Los Angeles in 1993 adopted efficient water rates during droughts and why, 1 yr later, Tucson rescinded the rates and Los Angeles almost rescinded them. The concept of political feasibility explains why and how, after the drought, the Los Angeles innovations to rate design achieved efficiency and political feasibility, avoiding reversion to the previous, inefficient rates, by separating economic efficiency from political feasibility in both the rate design and the rate reform process. (*JEL* D42, D70, H00, L38, L51, L97, Q25, Q28, Q48, Q58)

I. INTRODUCTION

This article defines the concept of political feasibility for appointed and elected rate approval officials. Applying the concept of political feasibility, this article prescribes necessary and sufficient conditions for rate reform such that a public choice model predicts that an efficient rate design will be selected over an inefficient one.

The concept of embedded cost (EC) rate design sets fixed charges (such as a customer charge) to collect revenue sufficient to cover fixed costs and variable charges (a commodity charge) equal to average variable cost (a declining block[1] structure). Long-run marginal cost (LMC) is typically greater than the system average cost[2] (American Water Works Association [AWWA], 2000), so that a single-part tariff based on LMC rate design would collect revenue that exceeds cost. A two-part tariff can achieve economic efficiency while meeting the revenue constraint by setting the price equal to LMC and rebating excess revenue with a negative fixed charge unrelated to the amount consumed (Coase, 1946).

Political feasibility depends on relative wealth effects among political support groups—water rate payers with divergent interests and

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1. The first unit's price equals the fixed charge plus the variable charge while every unit thereafter is priced at the variable charge alone, the essence of a declining block structure.

2. LMC can exceed long-run average cost for a natural monopoly. See Hall (2009) for a numerical example of a water utility with discrete additions to capacity. Each additional plant has falling average cost up to plant capacity. For supply greater than marginal plant capacity, an additional, higher cost plant is added that represents the least cost addition in the service territory.

ABBREVIATIONS

AWWA: American Water Works Association
BU: Billing Unit
DWP: Department of Water and Power
EC: Embedded Cost
LMC: Long-Run Marginal Cost

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preferences for one over another rate design. Customers with high demand ("large customers") prefer an EC rate design, with large fixed charges and small variable charges. Customers with smaller demand ("small customers") prefer an LMC rate design. Politically feasible rate reform balances the wealth effects among political support groups.

In response to the 1976–1977 drought, Tucson, Arizona, implemented LMC rates. At the same time, a 1977 Blue Ribbon Committee on rate design in the City of Los Angeles, appointed by Mayor Tom Bradley, concluded that such a design would not be politically feasible and chose instead to switch from declining block rates to a flat rate structure (Mayor's Blue Ribbon Committee on DWP Rate Structure, 1977). One year later, the Tucson City Council was voted out *en mass* because of the water rate reform (Martin et al., 1984). At the end of a 6-yr drought from 1987 to 1992,[3] Los Angeles Mayor Tom Bradley appointed the 1991–1992 Mayor's Blue Ribbon Committee that recommended an LMC rate design (Mayor's Blue Ribbon Committee on Water Rates, 1992) to the Los Angeles Department of Water and Power (DWP) Board of Commissioners, which is appointed by the Mayor to oversee the DWP and normally oversees changes in the rate design. The Board approved and forwarded the rate design and it was subsequently adopted by the City Council as an ordinance in 1992, with support from only two of the five council members representing the hotter, interior San Fernando Valley, whose residents use more water on average than the rest of the city. Mayor Bradley retired, and after the drought, Mayor Richard Riordan was elected[4] with strong support from voters in the San Fernando Valley who voted out a long-standing city council member, one of the two San Fernando Valley council members who supported the 1992 rate design,[5] and elected an opponent[6] who campaigned against the rate design. The following summer when the higher summer second tier price went into effect, the Mayor received complaints from his constituents, and in response, Mayor Riordan reconstituted and appointed the 1993–1994 Mayor's Blue Ribbon Committee[7] and directed them to revisit the rate design (Mayor's Blue Ribbon Committee on Water Rates, 1994) and make any recommended changes to the Board of Utilities, all appointed by the new Mayor.

Becker's (1983) public choice model predicts that during normal rainfall years, EC rate design will be chosen and that droughts open windows of opportunity to switch to LMC rates. This type of rate reform occurred in 1977 in Tucson (Martin et al., 1984) and in 1992 in Los Angeles (Hall and Hanemann, 1996). Becker's model explains why Tucson switched back to the old rate design after the drought but leaves unexplained why Los Angeles did not (Hall, 2000).

This article develops an alternative public choice model that explains both the rate reform during droughts and the retention of LMC rates by Los Angeles during normal rainfall years. Section II reviews Peltzman's model of price regulation of private industry and generalizes it to also apply to a municipal utility. This generalized model, new here, explains how droughts open windows of opportunity for efficient LMC rate reform. Section III defines political feasibility and compares and contrasts it to economic efficiency and the Kaldor-Hicks criterion. An application of the concept of political feasibility prescribes necessary and sufficient conditions for successful, economically efficient rate reform during normal rainfall years. The generalized Peltzman model predicts and explains why Los Angeles did not switch back to the old rate design after the drought ended. Section III provides an example of how public choice models can be used to prescribe efficient rate design. Section IV describes some generalizations for applying public choice models not just to predict public choices but also to design and prescribe policy to increase the efficiency of government.

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

4. Mayor Bradley, a Democrat, retired and did not run for reelection. Mayor Riordan is a Republican.

5. The council has 15 members who serve staggered 4-yr terms, elected in odd-numbered years. In 1993, two of the five San Fernando Valley council members (Districts 3 and 7) were up for reelection, and both voted for the 1992 new rate design.

6. The opponent previously served as staff to the council member she defeated in 1993 in District 3.

7. The author served on both the 1991–1992 and the 1993–1994 committees.

II. PELTZMAN'S MODEL, DROUGHTS, AND RATE REFORM

This section extends Peltzman's (1976) model (whose work is based on that of Stigler, 1971) for application to a municipal utility and shows how a drought may result in a shift from EC to LMC rate design.

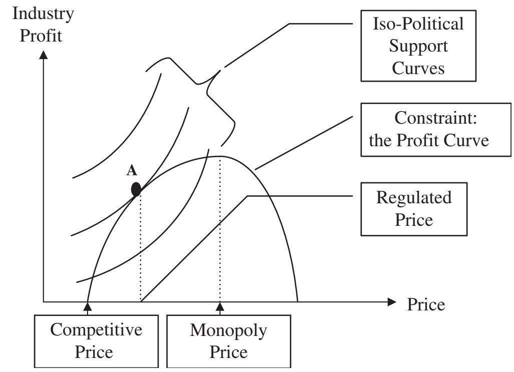
A. Peltzman's Model

In Peltzman's model for a regulated industry, the variables in the politician's political support function are profit of the regulated industry and the price paid by the consumer, shown on the axes in Figure 1. Isopolitical support curves give combinations of industry profit and prices facing consumers resulting in political support from consumers and industry that leave the politician with the same support level. Higher isopolitical support curves are up and to the left. If the politician could increase industry profit while holding price constant, the politician benefits with greater political support from industry. If the politician could lower price while holding profit constant, the politician benefits with greater political support from consumers. If the politician could somehow both lower the price to consumers and increase industry profit, the politician receives increased support from both consumers and industry.

Because of the logic of collective action (Olson, 1965), the cost of organizing and influencing the regulators is lower for members of the smaller group, the regulated industry, relative to the larger group, the consumers. Additionally, the average benefit of influencing regulators is lower for members of the larger group, the consumers, relative to the average benefits to the regulated industry. In the extreme case of monopoly, there are no free-rider effects when industry acts to influence the outcome. Consequently, the family of isopolitical support curves is positively sloped.

In Peltzman's model, the constraint facing the regulator-politician is given by the profit function that shows zero industry profit at the competitive price, maximum industry profit at the monopoly price, and falling industry profit for prices greater than the monopoly price (Figure 1). Subject to the constraint, the politician selects the regulated price to reach the highest isopolitical support curve at point *A*. Peltzman's model predicts an inefficient outcome for price regulation.

FIGURE 1
Peltzman's Model



Description: Peltzman describes the regulator's trade-off as between industry profit and the regulated price. The constraint the regulator faces is given by the profit curve. The profit curve begins at a zero profit if the regulator sets price equal to the price in a competitive industry and rises to maximum profit if the regulator sets price equal to that chosen by a monopolist. A family of isopolitical support curves, similar to indifference curves, shows combinations of price and industry profit that provide the regulator with a combination of political support from consumers and industry that remains constant along a curve. Moving from upper right to lower left along an isopolitical support curve, a reduction in industry profit reduces political support from the regulated industry, but the corresponding decrease in price wins political support from consumers, holding total political support constant. A movement that simultaneously increases industry profit and reduces price raises political support from both the regulated industry and the consumers, moving the regulator to a higher political support curve. The regulator optimizes by attaining the highest isopolitical support curve subject to the profit curve constraint, at point *A* above the regulated price.

Note that the economically efficient solution for a regulated industry is a corner solution in Peltzman's model. Moving from a less efficient solution to a more efficient solution does not generate a welfare increase that can be used to compensate losers by winners, so the constraint rules out policies that increase economic efficiency. Municipal utilities are legally constrained to operate without generating a profit, so the constraint in Peltzman's model is not applicable to price regulation of a municipal utility. The following reformulation of Peltzman's model extends its applicability to both regulated investor-owned utilities and municipal utilities. The extension also permits the possibility that a policy change can generate economic gains that can be divided among political support groups, as will be demonstrated in Section III.

B. Generalization of Peltzman's Model

Peltzman's model can be generalized and applied to large and small residential customers. Both large and small water customers influence the political process. To benefit from a certain rate design, two groups of customers—large customers and small customers—vie with one another, providing (or withholding) votes and/or money to members of the city council. Elected officials can either be viewed as maximizing the number of votes (Peltzman, 1976) or wealth—more broadly defined to include power and influence (Hirshleifer, 1976). In Peltzman's model, the disadvantage goes to the group with more members, in this application, the more numerous small customers, for two reasons. First, voters must use resources to become informed about which politician is expected to act in their favor. For the smaller customer who sustains a smaller consumer surplus from the rate design, information costs on net make it less worthwhile to become informed. Second, a group with larger numbers has a greater cost to organize because of the free-rider effect (Olson, 1965). Peltzman (1976, p. 23) summarizes this argument with the politician's objective function in his equation (25), where the politician maximizes political support as a function of the wealth of the two groups.

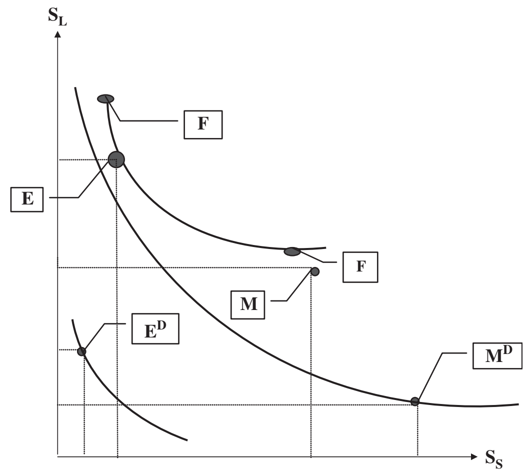
To generalize the Peltzman model so that it can be applied to a municipal utility, redefine the political support function and its partial derivatives by:

$$S = f(S_S, S_L), f_S, f_L > 0, f_{SS}, f_{LL} < 0, \text{and} f_{SL} = 0, \quad (1)$$

where the variables in the function are consumer surplus for large and small residential customers, shown on the axes in Figure 2, and the subscripts denote partial derivatives.[8] The political support function is quasiconvex, so that the isopolitical support curves are convex to the origin. The political support function is graphically a family of curves that can be visualized as similar to indifference curves, depicted in two dimensions as a family of isopolitical support curves, such as the curve going through points *FEF* in Figure 2. If elected officials can increase consumer surplus to both customers, they increase the political support they enjoy and move to a higher isopolitical support curve. An isopolitical support curve gives combinations of consumer surplus from large and small customers providing the same political support for election. In Figure 2, isopolitical support curve *FF* passes through point *E*. Moving along the curve downward from *E* toward the right shows combinations of consumer surplus that increase the consumer surplus of the small customer at the expense of the large customer, leaving constant the total political support for reelection.

The problem for city council members is to select a rate design that maximizes political support, subject to the constraint given by the set of points that describes the outcomes of the two rate designs. For a normal rainfall year, Figure 2 graphs two points, one for EC rate design, *E*, and the other for marginal cost

FIGURE 2
Rate Reform with Drought



Description: The axes measure consumer surplus for the small and large customers (S_S, S_L). The politician maximizes political support, $S = f(S_S,S_L)$, depicted as a family of curves convex to the origin, such as the curves through E^D and M^D, and curve *FEF*. During a normal year, when the constraint is given by the points *E* and *M*, the politician selects point *E* (EC rate design) to reach the highest isopolitical support curve. During a drought, points E^D and M^D give the constraint, and the politician selects point M^D (LMC rate design).

8. The use of consumer and producer surplus, rather than price and profit, would be the generalization of the model for application to the regulation of a natural monopoly in the example presented by Peltzman. The variables in the function are producer surplus, identical to monopoly profit, and consumer surplus that increases with a decrease in price. For this generalization, the isopolitical support curves are convex to the origin in comparison to Peltzman's formulation of the model.

rate design, *M*. Point *E* illustrates the consumer surpluses of the two water customers given EC rate design, and point *M* illustrates consumer surpluses under LMC rate design.

Point *M* is on a lower isopolitical support curve than point *E*, so during a normal rainfall year, EC rate design is selected over LMC rate design. This corresponds to the rate design prior to the drought for Tucson in 1976–1977 and the drought for Los Angeles in 1987–1992. If just two points, *E* and *M*, give the only alternative rate designs, city council members will select the EC rate design to maximize political support, so point *E* is shown in Figure 2 to be on a higher isopolitical support curve than point *M*, consistent with the examples of both cities.

C. Droughts: Windows of Opportunity for Rate Reform

Water utilities have low average variable costs and high per unit capital costs. Each additional incremental source of supply added to the system has a higher per unit capital cost than the previous increment, so that the long-run average cost is given by a set of discontinuous declining curves but with each new increment higher than the previous one (see the discussion and figures in Hall, 2009). EC rate design results in greater consumption relative to LMC rate design since EC rate design sets the price equal to the low average variable cost, while LMC includes the unit capital cost of the last increment added to supply.

During normal rainfall years, EC rate design allocates the capital costs of all necessary additional capital equally among residential consumers. Small consumers pay proportionately larger amounts of the capital costs, relative to the amount they consume, compared to the large consumers. In a symmetrical fashion, LMC rate design rebates any surplus revenue equally among consumers, so small consumers receive proportionately more surplus revenue.

The Appendix[9] analyzes the impact of rate reform on consumer surplus for large residential consumers relative to small consumers during normal rainfall years and during droughts. During both climate alternatives, the small consumer has an unambiguous improvement in consumer surplus due to rate reform, while the large consumer does not. For the large consumer, all the larger her consumption is relative to the small consumer, all the more likely the large consumer prefers EC over LMC rate design. A switch in climate regime from normal rainfall years to droughts does not necessarily result in the large consumer preferring rate reform.

Figure 2 illustrates why a drought might open the window of opportunity for rate reform. Points M^D and E^D give the consumer surpluses for LMC and EC rate design during a drought, and points *M* and *E* give the surpluses during normal rainfall years. *E* is on a higher isopolitical support curve than *M* and the politicians select EC rate design during normal years. M^D is on a higher isopolitical support curve than E^D and the politicians select LMC rate design during droughts. The relative changes, in gains and losses between the large and small customers during normal rainfall years and droughts, explain why droughts open windows of opportunity for rate reform.[10]

The size of the welfare loss increases with the difference between the EC commodity charge and the LMC commodity charge. With increasing incremental costs of supply, during droughts, the difference between the commodity charges for the two rate designs is larger than during normal rainfall years. All the worse the drought, all the higher the incremental cost of water and greater the likelihood that rate reform will occur.

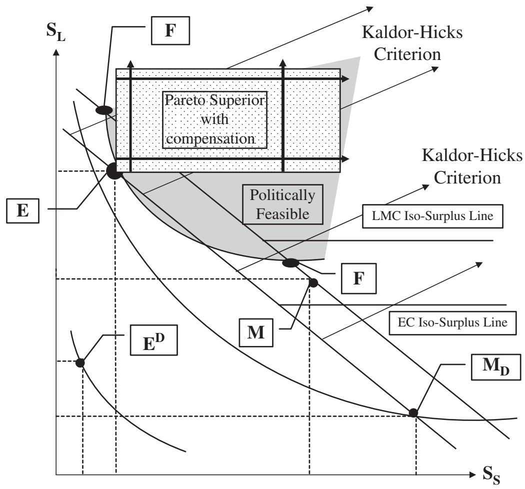
III. POLITICAL FEASIBILITY AND ECONOMIC EFFICIENCY IN NORMAL YEARS

This section defines the concept of political feasibility and examines the innovative features of the Los Angeles rate design, explaining how Los Angeles retained LMC rates after the drought ended. In Figure 3, a negatively sloped 45° line through point *E* traverses combinations of consumer surplus where the total of the sum of the surpluses for the consumers is constant; call this line the EC isosurplus line. The Kaldor-Hicks criterion requires that potential compensation be sufficient for a welfare improvement but does not require that the compensation be paid. Prior to rate reform, any point to the right and above the EC isosurplus line meets the Kaldor-Hicks criterion.

9. Available from the author at http://www.csulb.edu/~dhall/.

10. For a numerical example, see Hall (2009) in this issue. For more general treatment, see the Appendix.

FIGURE 3
Political Feasibility



Description: The axes measure consumer surplus for the small and large customers (S_S, S_L). The politician maximizes political support, $S = f(S_S, S_L)$, depicted as a family of curves convex to the origin, such as the curves through E^D and M^D, and curve *FEF*. During a normal year, politically feasible combinations of consumer surplus are on and above the curve *FEF*. The 45° line through points *E* and M^D—the EC isosurplus line—gives combinations of consumer surplus for which total consumer surplus is constant; points above the line meet the Kaldor-Hicks criterion. During a normal year, when the constraint is given by the points *E* and *M*, the politician selects point *E* (EC rate design) to reach the highest isopolitical support curve; points in the area shaded with dots to the right and above the point *E* are Pareto superior, increasing consumer surplus of either (or both) the large or the small customer without reducing surplus of the other. During a drought, points E^D and M^D give the constraint, and the politician selects point M^D (LMC rate design). The 45° line through points *MFF*—the LMC isosurplus line—gives combinations of consumer surplus for which total consumer surplus is constant; a two-part tariff can expand the constraint to include any point on this line.

The area above and to the right of point *E* increases consumer surplus for the large or small customers, or both, results that are Pareto superior relative to the EC rate design at point *E*. A set of axes are drawn through point *E*; the upper right quadrant defined by those axes is illustrated in Figure 3 with dots and labeled "Pareto superior with compensation." Any point in that area increases consumer surplus to at least one consumer without reducing consumer surplus to any other. Any new rate design that resulted in a combination of surpluses in that area would be a Pareto superior move.

A. Political Feasibility

Define *political feasibility* as outcomes on or above the existing isopolitical support curve. The shaded area above the curve *FEF* in Figure 3 illustrates the politically feasible set. During normal years, the LMC rate design, point *M* in Figure 3, meets the Kaldor-Hicks criterion but is not politically feasible in the figure. What we wish to identify are the innovative features of LMC rates implemented in 1995 and the rate reform process in Los Angeles that made such rates politically feasible in normal years.

While point *M* is not politically feasible, it is possible to specify an LMC rate design that is politically feasible, even if the rate design is not Pareto superior (with compensation). Recall that the purpose of the negative fixed charge is to equate required revenue to actual revenue. The fixed charge can be varied between the large and the small customers. As long as the commodity charge is kept constant, total consumer surplus does not change. The 45° line that traverses through points *MFF* holds constant total consumer surplus; call this the LMC isosurplus line. Points between *FF* on this line are politically feasible. The model prescribes a rate design and a rate reform process that achieves shares of consumer surplus on the line segment *FF*. While the model simplifies with negative fixed charges, a two-part increasing block tariff can also result in a point on *FF*.

The practical problem is to jointly prescribe a rate *design* and a rate reform *process* that separate the efficiency characteristics of the rate design from the allocation of wealth. This must be accomplished in a fashion that will withstand legal challenge, as a *prima facie* reasonable exercise of discretionary authority. Simply altering the fixed charge among all customers in a seemingly arbitrary fashion will not meet this test.

With a two-part increasing block tariff, set the second tier price to achieve economic efficiency and adjust the initial tier price to achieve zero net revenue; such a rate design meets the general legal standards, "just and reasonable, and bears a rational relationship to a legitimate government interest" (AWWA, 2000, p. 280). As long as the politically feasible thresholds are not adjudged "unjust or unreasonable," the LMC rate reform advocated here should pass legal muster. In *Brydon v. East Bay Municipal Utility District*, the court held in favor of inclining block rates to achieve conservation because the state mandates conservation and large users add the burden of higher incremental costs of additional water (AWWA, 2000, p. 282).

During the last year of the drought, when the Los Angeles City Council adopted the LMC rates, the Council altered the 1991–1992 Mayor's Blue Ribbon Committee's recommendations. All residential customers paid the same lower initial tier price up to the threshold amount, after which all paid the higher second tier price for additional consumption.[11] In order to make the recommendations more acceptable to the large water users in the San Fernando Valley, the Council raised the citywide threshold to 200% of the seasonal median amount during the drought: 22 and 28 BUs per month in the winter and summer, respectively. Shifting the threshold to the right reduced the percentage of customers that actually paid the marginal cost of water;[12] most small residential customers paid the initial tier price and consumed less than the threshold, resulting in lost efficiency. But shifting the threshold for political reasons presaged the innovation of the 1993–1994 committee.

After the drought ended, San Fernando Valley customers, living in an inland, hotter climate with larger lots and more landscaping, experienced substantial increases in water bills, especially during summer, and that fall they voted out of office one of the two Valley council members who supported enactment of the 1991–1992 committee's recommendations and whose opponent strongly opposed the rate reform. This corresponds to the political support curve *FEF* in Figure 2, with two points—*E* and *M*—giving the constraint, where point *E* is on a higher political support curve. Richard Riordan won the mayoral election with substantial support from San Fernando Valley voters. As supporters of Mayor Riordan, Valley residents demanded that the Mayor repeal the LMC rate design, point *M*, and return to the previous design, point *E*. The Mayor reconstituted[13] the committee and appointed three new members from the Valley, all of whom initially demanded repeal of the rates. Planned in concert with city council members representing the Valley, the Mayor's office scheduled a series of public hearings for the 1993–1994 committee to hold in the Valley, so that Valley residential water customers with larger demand could voice their dissatisfaction with the marginal cost rate design. These were well attended and covered prominently in the news, depicted as voicing substantial public dissatisfaction with the 1991–1992 rate design. The new members of the committee called for a return to EC rate design, point *E*. Any recommendation by the committee as a matter of normal procedure would be received by the DWP Board of Commissioners, all new appointees by the new Mayor. As a political matter, the Board of Commissioners would not forward a recommendation in favor of LMC rates by the committee, if opposed by Valley representatives on the committee. The Northridge earthquake delayed the hearings and allowed time for the 1993–1994 committee to develop innovative alternatives rather than simply repeal the rate ordinance.

The 1993–1994 committee wanted to achieve the benefits of a more efficient rate design but faced the practical task of finding

11. The upper tier price was set equal to $2.98/billing unit (BU) in summer and $2.33/BU in winter. A BU equals 748 gallons.

12. See Figure 1 in Hall (2009) in this issue of *CEP*.

13. The 1991–1992 committee included 12 members, 11 of whom were reappointed. One representative of an environmental group appointed by the previous mayor was not reappointed by Mayor Riordan. Mayor Riordan added three new members, initially opposed to the rate reform, from the San Fernando Valley. Two of the original committee members were from the Valley, bringing to five the total representatives from the Valley. In addition, the Mayor appointed the ex-officio members of the committee representing the DWP Board of Commissioners.

a rate design that would be perceived as more equitable to large residential customers in the hotter San Fernando Valley as well as small residential customers along the coast. Committee members representing the San Fernando Valley agreed that a rate design would be considered "fair" if everyone paid roughly the same average price. Water utility engineers offered various rationales based on cost allocation principles (AWWA, 2000) for fair average prices to differ among residential customers by geographic region. The solution to this problem is to divide the residential customer class into homogeneous subgroups, illustrated in Figure 3 with two subgroups—large and small residential customers—and let the politicians set the threshold for each subgroup, so that the average price paid by that group is considered fair by whoever has the authority to set the rate design.

The 1993–1994 committee recommended a change in the rate design, segmenting the market into 64 homogeneous subgroups, based on lot size, temperature, seasons, and family size.[14] Within each subgroup, the threshold is 120% of the median consumption in that subgroup during the drought[15] compared to the previous rate design threshold at 200% of the citywide median consumption. These changes reduce the threshold for smaller water customers and increase the threshold for larger customers, achieving an increase of consumer surplus for larger customers, while decreasing consumer surplus for smaller water consumers. This is illustrated in Figure 3 as a movement from *M* to somewhere between *FF*.

Abstracting this principle to two residential subgroups, the constraint in Figure 3 is no longer just two points (*E* and *M*). Given that the threshold is a continuous variable, the constraint is given by the 45°, continuous LMC isosurplus line that passes through points *MFF*. The 1993–1994 committee's innovation added policy choices along the line segment *FF* that are politically feasible, permitting the relative political strength of the different groups to determine the final outcome along *FF*, allocating the wealth (consumer surplus) between the large and small customers.

14. See tables 2 and 4 in Hall (2009) in this issue.

15. Voluntary conservation during the drought exceeded expectations. Average consumption dropped from about 210 gallons/day to about 170 per household.

Peltzman (1976, p. 219) discusses the possibility of breaking a group into two smaller groups. He also sets up his model so that the officeholders or candidates can select the size of each group and the amount they transfer to the group. In essence, the Los Angeles example shows that it may be necessary to break a group into multiple smaller groups for greater variation in wealth transfer in order to achieve political feasibility.

B. Additional Subgroups and Increases in Efficiency

In addition to solving the political problem, more homogeneous demand for water in each subgroup results in greater economic efficiency since more customers actually buy some water at the higher second tier price equal to the marginal cost. This is an accomplishment of the rate design developed by the 1993–1994 committee that the AWWA (2000) rates manual misses, as it incorrectly concludes, "small and moderate users do not receive the strong incentives of marginal cost rates" (p. 167). The AWWA manual has in mind a single threshold for all customers, such as the 1991–1992 committee rate design.

While Figure 3 depicts a world in which there are just two groups, one could generalize by adding an additional axis to the figure measuring consumer surplus for a third subgroup, wherein an isopolitical support surface defines the boundary of the politically feasible set across three subgroups. A larger percentage of all residential customers would face the second tier price for the marginal unit compared to a design based on two subgroups. A larger percentage facing the upper tier marginal cost rate implies that the new constraint created by multiple subgroups, an isosurplus plane in three dimensions, results in a sum total surplus greater than or equal to the total for two subgroups as given by the LMC isosurplus line in Figure 3.

The addition of homogeneous subgroups achieves greater efficiency, a shift to a higher isosurplus curve. The 1991–1992 rate design sets the threshold at 200% of median use for the entire city. The 1993–1994 rate design sets the threshold for each subgroup at 120% of median use for the subgroup. For the 1993–1994 rate design, smaller customers have lower thresholds than the 1991–1992 rate design, so more of the smaller customers also consume water in the higher block and face the marginal cost incentive.[16] The 1993–1994 rate design had a different threshold for each homogeneous subgroup (but only two price tiers that were the same across subgroups); a two-tier, multiple subgroup thresholds rate design provides the marginal cost price signal to more customers.

Peltzman's model predicts that government will not achieve efficiency because, as Peltzman (1976, p. 211) puts it, "the political process does not usually provide the dichotomous treatment of resource allocation and wealth distribution so beloved by welfare economists." Peltzman's implicit prescription to achieve efficiency is to devise processes for policy decision making that dichotomously separate efficiency and wealth distribution, allowing government to enhance efficiency. In this application to municipal utility rate design, the dichotomy is achieved by a rate reform *process* whereby the political decision makers determine the relative political strengths of different support groups, and these decision makers help partition the support groups and adjust the thresholds, but only the thresholds and not the entire rate design. The 1993–1994 committee deliberated on this issue, separating the components of both the rate design and the rate reform process to achieve three separate goals (revenue stability and zero economic profit, economic efficiency and water conservation, and political feasibility). A Technical Advisory Committee of economists formed by the Blue Ribbon Committee calculated the LMC for the second tier price, the proposed rate ordinance included an adjustment to the initial tier price at regular intervals by the utility management to collect required revenue, and the Board of Commissioners and the City Council focused on the partitioning of support groups and adjustments to the thresholds but did not alter the initial and second tier prices.

The Mayor's office referred the 1993–1994 committee's recommendations to the DWP Board of Commissioners. Reflecting the political strength of the large water users, the Board of Commissioners altered the thresholds for all lot sizes in higher temperature zones and added another subgroup for the largest lot sizes (greater than 1 acre).[17] The Board's decision to add another subgroup transferred consumer surplus from those with smaller lot sizes to those with the largest lot size, generally benefiting high-income families. The Board of Commissioners then submitted to the City Council their revision of the recommendations of the 1993–1994 committee.

The City Council further altered the rate design, again focusing on the subgroups and their thresholds. The Council increased the consumer surplus for low-income families by increasing the threshold based on a family size augmentation and by making the augmentation automatic in 24 low-income postal zones.[18] Larger families consume more water, so the Council further shifted consumer surplus from smaller to larger water customers, but in this case benefiting low-income families. In 1995, the Council approved the rate ordinance.

Since the 1995 rate reform, the rate design has been modified five times during normal rate hearings, but the thresholds have not changed. During these rate hearings, the second tier price has been adjusted upward and the initial tier price has been adjusted downward, all minor adjustments. For 14 years the design has achieved political feasibility.

Hirshleifer (1976, p. 242) writes, "Peltzman's identification of the regulator with the elected politician is too radical a simplification. This assumption precludes analysis of the substantially different roles played by the various classes of actors in the political drama," in particular, civil servants. Utility management can influence and stymie rate reform. The AWWA (2000, p. 292) rates manual makes clear that the principal objective of rate design is financial stability to meet revenue requirements and revenue bond covenants. In the case of Los Angeles, the city charter sets financial ratio constraints that determine the revenue requirement (Hall and Thomas, 1984). By adjusting the initial tier price automatically (with city council oversight), the rate design avoids the traditional trade-off between revenue stability and

16. Figure 1 in Hall (2009) in this issue illustrates that a finer partitioning of customer classes can achieve greater efficiency. The 1991–1992 rate design had a single threshold for all customers, such as T_2 in Figure 1 of the accompanying article. The single threshold rate design at T_2 provides the marginal cost price signal to the large but not to the small customer. In the case of two subgroups, Figure 1 illustrates setting the small customer's threshold at T_1 and the large customer's threshold at T_3. The two thresholds, T_1 and T_3, for the two subgroups, provide the marginal cost signal to both customers.

17. See table 3 in Hall (2009) in this issue.

18. See table 4 in Hall (2009) in this issue.

efficiency associated with LMC rate design. This innovation by the 1992–1993 committee removed objections to LMC rate design raised by DWP management who then agreed to not oppose rate reform.

The rate reform process included the Technical Advisory Committee of economists to calculate the LMC, which determined the second tier price. By creating subgroups with different thresholds, and allowing the rate approval body (DWP Board of Commissioners and city council) to adjust the number of subgroups and thresholds, political feasibility is separated from efficiency in both the rate design and the rate reform process. These innovations to rate design allow for the "dichotomous treatment of resource allocation and wealth distribution" that Peltzman (1976, p. 211) implicitly prescribes.

IV. CONCLUDING REMARKS AND EXTENSIONS

The generalization of Peltzman's model predicts a switch to LMC rates during severe droughts and a return to EC rates after droughts are over. Los Angeles, however, developed an innovation for rate design and kept the LMC feature after the drought ended. The concept of political feasibility, defined here, can be applied to design efficient residential rates that are politically feasible during normal years. The rate design sets thresholds between a lower initial tier price and the higher LMC second tier price. Political feasibility is achieved by creating a number of homogeneous subgroups, and setting thresholds that vary among subgroups, thereby expanding the set of policy options to include an efficient and politically feasible rate design. There is a general lesson: successful rate reform does not require an event such as a drought. Instead, a form of price discrimination[19] allows for wealth redistribution so that winners can compensate losers or at least reduce losses to a politically acceptable level and efficiency gains become politically feasible.[20]

Peltzman's original model does not allow the possibility that government intervention can achieve economic efficiency, excepting a corner solution in Figure 1 at the competitive price. A contribution potentially larger than water rate reform is in the answer to this question: what in this extension of Peltzman's model leads to the result of an improvement in economic efficiency from policy reform? The answer lies in the way the model was generalized.

The application to rate design for municipal water utilities required a generalization of Peltzman's model, designed on the tradeoff between the surplus of one group versus the surplus of another group. This generalization lends itself to empirical testing and easily identifies Pareto superior as well as Pareto inferior alternatives, whereas Peltzman's construct only admits policy choices that are inefficient, excepting the corner solution noted above. Finally, this generalization leads to a definition of the concept of political feasibility, as the set bound by the isopolitical support curve prior to policy reform.

A second difference between Peltzman's original model and this one is the constraint, in other words, the opportunity set of policy options. This generalization allows for the possibility that economists may identify new policy options that make Pareto improvements, and a policy decision-making process that dichotomously determines wealth distribution separately from efficiency. The surprise of the experience in Los Angeles is that it is possible to create and implement policies that separate Pareto improvements from a decision-making process that determines wealth allocation in the case of municipal water rate reform. A similar experiment is under way for electricity rates wherein the threshold between initial lower tiers and the higher tier depends on location, either inland or coastal, affecting electricity demand for air-conditioning—especially during summer (Los Angeles Department of Water and Power, 2008). The concept of political feasibility and this reformulation of Peltzman can assist those who seek similar success in other policy venues. As a field of inquiry, public choice is predictive, but public choice can also be prescriptive—to design and identify more effective economic policies that policy decision makers find to be politically feasible.

Policies that achieve greater economic efficiency also create additional wealth. Such policies must meet the Kaldor-Hicks criterion but not the Pareto superior criterion (with

19. I thank the editor for pointing this out.

20. Hall (2009) compares the Los Angeles rate design with alternative designs and argues that water scarcity provides ample opportunity worldwide to afford further water rate reform based on the model design presented here.

compensation) to be politically feasible.[21] Necessary conditions are to (1) identify a continuous policy variable that shifts wealth without affecting efficiency, thereby expanding the policy opportunity set and (2) establish a policymaking process that confines policy makers to the selection of the wealth-shifting variable, leaving intact the efficiency-improving variable. What is sufficient is that at least one (more) efficient policy alternative is politically feasible. The result of such policy design is the prediction by public choice theory that elected officials[22] will maximize support by selecting a more efficient policy. What remains to be seen is whether economists can repeat this success in the innovation of policies other than utility rate design.

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21. A politically feasible policy, however, does not necessarily meet the Kaldor-Hicks nor the Pareto Superior criteria. For example, in Figure 3, rate designs could result in combinations of consumer surplus above the curve *FEF* but below the EC isosurplus line, and these designs would be politically feasible.

22. For countries without democracy, one may assume that rulers have preferences that describe tradeoffs among the consumer surpluses of different groups. If we define benevolent dictators as preferring higher consumer surplus for each and every group, then the isopolitical support curves of the shape given in Figures 2 and 3 would describe the rulers' preferences, and the analysis would be applicable.

A NOTE FROM THE AUTHOR

"Since this paper and its companion were accepted, the growing severity of the drought has resulted in water rate reform as predicted herein. The Colorado River watershed, a major water source for California, has experienced a drought for the last 8 of 9 years. After a record dry spring in the Sierra Nevada Mountains, another major water source for California, in June 2008 the Governor of California declared a drought. For a third year in a row, Southern California has faced a water shortage, and the City of Los Angeles, on June 1, 2009, declared a 15% shortage and implemented drought rates, reducing the threshold by 15% between the low tier rate charged for initial amounts of water and raising the high tier rate charged for amounts greater than the threshold. The high tier rate is an eye popping $5.48 per 100 cubic feet (748 gallons) of water. This equals a price equivalent to $2,383.80 per acre foot, the price expected to result in a sufficient reduction in consumption to accommodate the shortage."

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