Prescriptive Public Choice: Application to Residential Water Rate Reform - with Appendix

by

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Abstract

Peltzman's model of price regulation predicts inefficient prices for regulated firms; based upon 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 paper 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 paper 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Tucson in 1976 and Los Angeles in 1993 adopted efficient water rates during droughts and why, one year later, Tucson rescinded the rates and Los Angeles almost rescinded them.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.

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I. Introduction

This paper defines the concept of political feasibility for appointed and elected rate approval officials. Applying the concept of political feasibility, this paper 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[2] structure). Long run marginal cost (LMC) is typically greater than the system average cost[3] (American Water Works Association, 2000), so that a single part tariff based upon 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 preferences for one over another rate design. Customers with high demand ("large customers") prefer an embedded cost rate design, with large fixed charges and small variable charges. Customers with smaller demand ("small customers") prefer a LMC rate design. Politically feasible rate reform balances the wealth effects among political support groups.

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[2] 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.

[3] Long run marginal cost 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.

In response to the 1976-77 drought, Tucson, Arizona, implemented long run marginal cost 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, 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 six year drought from 1987-1992[4], Los Angeles Mayor Tom Bradley appointed the 1991-92 Mayor's Blue Ribbon Committee that recommended a LMC rate design (Mayor's Blue Ribbon Committee, 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[5] 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[6], and elected an opponent[7] 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 1993-94 Mayor's Blue Ribbon Committee[8] and directed them to revisit the

[4] The drought began in the fall, 1986, and the "rainfall year" that measures precipitation crosses two calendar years.
[5] Mayor Bradley, a Democrat, retired and did not run for re-election. Mayor Riordan is a Republican.
[6] The council has 15 members who serve staggered 4-year terms, elected in odd-numbered years. In 1993, two of the five San Fernando Valley council members (Districts 3 and 7) were up for re-election, and both voted for the 1992 new rate design.
[7] The opponent previously served as staff to the council member she defeated in 1993 in District 3.
[8] The author served on both the 1991-92 and 1993-94 committees.

rate design (Mayor's Blue Ribbon Committee, 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 paper 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.

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. Iso-political 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 iso-political 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 iso-political 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 iso-political support curve at point A. Peltzman's model predicts an inefficient outcome for price regulation.

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

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

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[9]. The political support function is quasi-convex, so that the iso-political 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 iso-political 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 iso-political support curve. An iso-political support curve gives combinations of consumer surplus from large and small customers providing the same political support for election. In Figure 2, iso-political support curve FF passes through point E. Moving along the curve downward from E towards the right shows combinations of consumer surplus that increase

[9] 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 iso-political support curves are convex to the origin, in comparison to Peltzman's formulation of the model.

the consumer surplus of the small customer at the expense of the large customer, leaving constant the total political support for re-election.

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 embedded cost rate design, E, and the other for marginal cost 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 iso-political 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 1976-77 and the drought for Los Angeles in 1987-92. 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 iso-political 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, this issue). 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[10] 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 embedded cost over long run marginal cost 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 iso-political support curve than M, and the politicians select EC rate design during normal years. M^D is on a higher iso-political 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[11].

[10] Available from the author at http://www.csulb.edu/~dhall/.
[11] For a numerical example, see Hall (2009) in this issue. For more general treatment, see the Appendix.

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-degree 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 iso-surplus 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 iso-surplus line meets the Kaldor-Hicks criterion.

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 embedded cost 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 iso-political 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 a 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 small customers. As long as the commodity charge is kept constant, total consumer surplus does not change. The 45-degree line that traverses through points MFF holds constant total consumer surplus; call this the LMC iso-surplus 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 *primae facia* 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 1991-92 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[12]. 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 billing units 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[13]; 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 1993-94 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

[12] The upper tier price was set equal to $2.98/BU in summer and $2.33/BU in winter. A billing unit (BU) equals 748 gallons.
[13] See Figure 1 in Hall (2009) in this issue of *CEP*.

members who supported enactment of the 1991-92 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[14] the Committee, and appointed 3 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 1993-94 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 1991-92 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 Department of Water and Power (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 1993-94 committee to develop innovative alternatives rather than simply repeal the rate ordinance.

[14] The 1991-92 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 5 the total representatives from the Valley. In addition the Mayor appointed the ex-officio members of the Committee representing the DWP Board of Commissioners.

The 1993-94 committee wanted to achieve the benefits of a more efficient rate design, but faced the practical task of finding 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 upon 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 1993-94 committee recommended a change in the rate design, segmenting the market into 64 homogeneous subgroups, based on lot size, temperature, seasons, and family size[15]. Within each subgroup, the threshold is 120% of the median consumption in that subgroup during the drought[16], 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 degree, continuous LMC iso-surplus line that passes through points MFF. The

[15] See Tables 2 and 4 in Hall (2009) in this issue.
[16] Voluntary conservation during the drought exceeded expectations. Average consumption dropped from about 210 gallons per day to about 170 per household.

1993-94 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.

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 1993-94 committee that the AWWA rates manual misses, as it incorrectly concludes, "small and moderate users do not receive the strong incentives of marginal cost rates," (AWWA, 2000, p. 167). The AWWA manual has in mind a single threshold for all customers, such as the 1991-92 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 iso-political 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 upon two subgroups. A larger percentage facing the upper tier marginal cost rate implies that the new constraint created by multiple subgroups, an iso-surplus 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 iso-surplus line in Figure 3.

The addition of homogeneous subgroups achieves greater efficiency, a shift to a higher iso-surplus curve. The 1991-92 rate design sets the threshold at 200% of median use for the entire city. The 1993-94 rate design sets the threshold for each subgroup at 120% of median use for the subgroup. For the 1993-94 rate design, smaller customers have lower thresholds than the 1991-92 rate design, so more of the smaller customers also consume water in the higher block and face the marginal cost incentive[17]. The 1993-94 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

[17] Figure 1 in Hall (2009) in this issue illustrates that a finer partitioning of customer classes can achieve greater efficiency. The 1991-92 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.

and adjust the thresholds, but only the thresholds and not the entire rate design. The 1993-94 committee deliberated on this issue, separating the components of both the rate design and 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 1993-94 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 one acre)[18]. 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 1993-94 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 upon a family size augmentation and by making the augmentation automatic in 24 low-income postal zones[19]. 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.

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[18] See Table 3 in Hall (2009) in this issue.
[19] See Table 4 in Hall (2009) in this issue.

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 rates manual (American Water Works Association, 2000, p.292) makes clear that the principle 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 efficiency associated with LMC rate design. This innovation by the 1992-93 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 long-run marginal cost rates during severe droughts and a return to embedded cost rates after droughts are over. Los Angeles, however, developed an innovation for rate design, and kept the long run marginal cost 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, long run marginal cost 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[20] 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[21].

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 trade-off between the surplus of one group versus the surplus of another group. This generalization lends itself to empirical testing and easily identifies Pareto

[20] I thank the editor for pointing this out.
[21] 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 upon the model design presented here.

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 iso-political 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 underway for electricity rates wherein the threshold between initial lower tiers and the higher tier depends upon 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 compensation) to be politically feasible[22]. Necessary conditions are to: 1) identify a continuous policy variable that shifts wealth without affecting efficiency, thereby expanding the policy

[22] 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 curve FEF but below the EC iso-surplus line, and these designs would be politically feasible.

opportunity set, and 2) establish a policymaking process that confines policy-makers to the selection of the wealth-shifting variable, leaving in tact 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[23] 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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[23] For countries without democracy, one may assume that rulers have preferences that describe trade-offs among the consumer surpluses of different groups. If we define benevolent dictators as preferring higher consumer surplus for each and every group, then the iso-political support curves of the shape given in Figures 2 and 3 would describe the rulers' preferences, and the analysis would be applicable.

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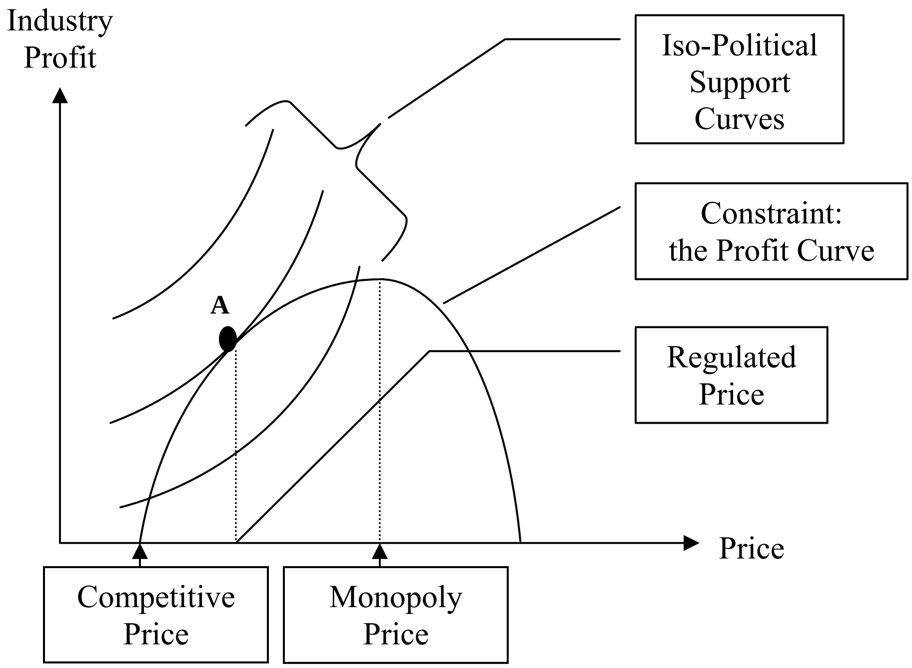
Abbreviations

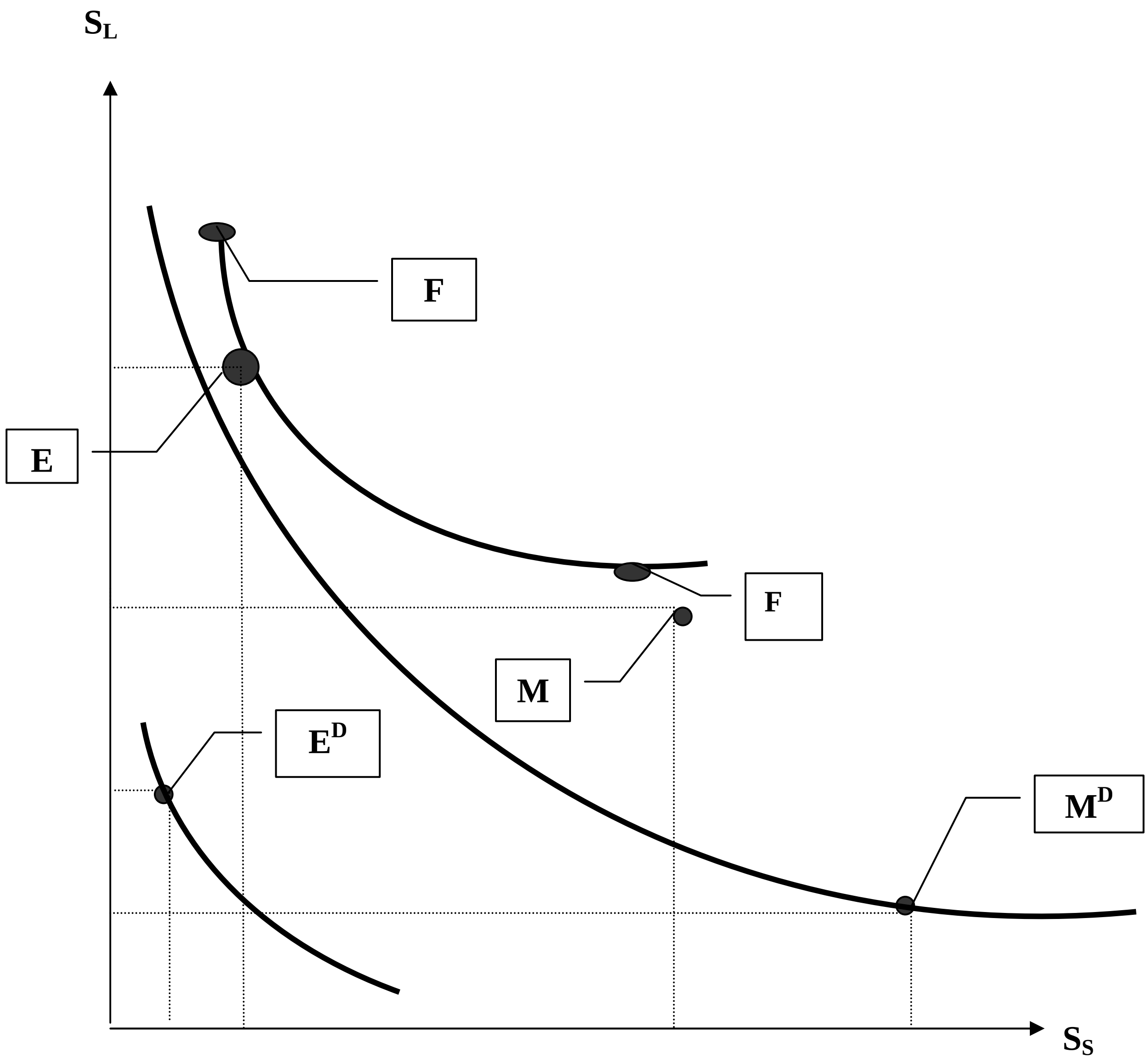
AWWA: American Water Works Association
BU: Billing Unit
EC: Embedded Cost
LMC: Long-Run Marginal Cost
DWP: Department of Water and Power

Figure 1: Peltzman's Model



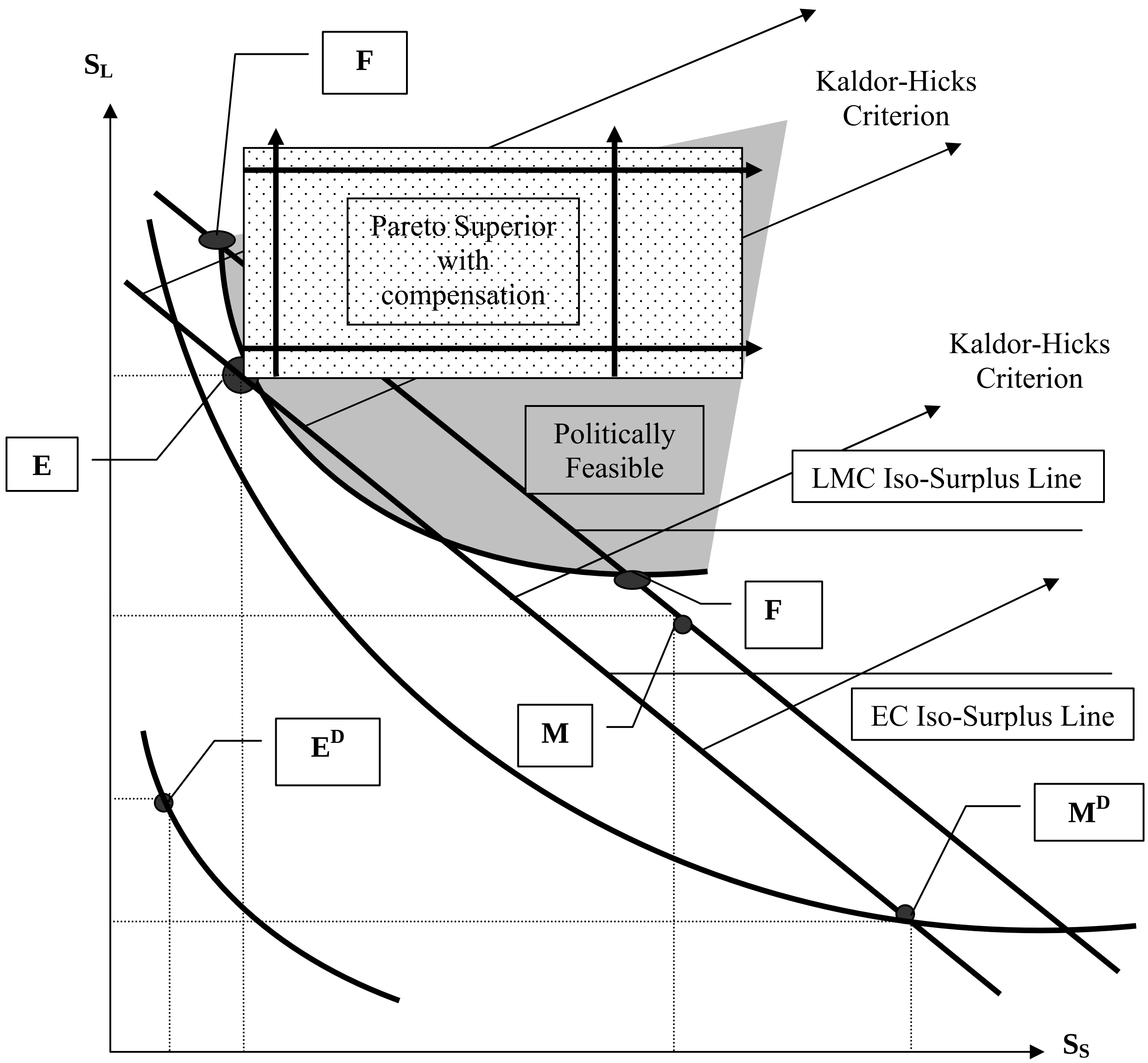
Description: Peltzman describes the regulator's trade-off as between industry profit and the regulated price. The constraint the regulator faces is given by the profit curve. The profit curve begins at a zero profit if the regulator sets price equal to the price in a competitive industry, and rises to maximum profit if the regulator sets price equal to that chosen by a monopolist. A family of iso-political 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 iso-political 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 consumers, moving the regulator to a higher political support curve. The regulator optimizes by attaining the highest iso-political support curve subject to the profit curve constraint, at point A above the regulated price.

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 (embedded cost rate design) to reach the highest iso-political support curve. During a drought, points E^D and M^D give the constraint, and the politician selects point M^D (long-run marginal cost rate design).

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 curve FEF. The 45-degree line through points E and M^D – the EC iso-surplus 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 (embedded cost rate design) to reach the highest iso-political 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 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 (long-run marginal cost rate design). The 45-degree line through points MFF – the LMC iso-surplus 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.

Appendix: Change in Consumer Surplus from Rate Reform

Problem setup

Let $0 < C_1/Q_1 < C_2/Q_2 < C_3/Q_3$ denote increasing incremental per unit capital costs of supplying quantities Q_0, Q_1, Q_2, Q_3, with associated constant short run marginal cost, m, where Q_0 is available during normal rainfall years with zero capital costs.

Define the small consumer as having a smaller quantity demanded at every price relative to the large consumer, equal to $Q_m^S < Q_m^L$ when the price is m, $Q_1^S < Q_1^L$ when the price is $m + C_1/Q_1$, $Q_2^S < Q_2^L$ when the price is $m + C_2/Q_2$. During normal rainfall years, let $Q_m^S + Q_m^L = Q_0 + Q_1 + Q_2$, and $Q_1^S + Q_1^L = Q_0 + Q_1$, and during droughts, $Q_0 = 0$, $Q_m^S + Q_m^L = Q_1 + Q_2 + Q_3$ (so $Q_0 = Q_3$), and $Q_1^S + Q_1^L = Q_1 + Q_2$, shown in Figure A.1.

For a utility with just two consumers, the embedded cost rate design sets the commodity charge equal to m, and the fixed charge for each of the two customers equal to $\frac{1}{2}(C_1 + C_2)$ during normal years, and changes the fixed charge during droughts to equal $\frac{1}{2}(C_1 + C_2 + C_3)$. The long run marginal cost rate design has a commodity charge equal to $m + C_1/Q_1$ during normal years and $m + C_2/Q_2$ during droughts, with rebates equal to revenue in excess of total costs – $\frac{1}{2}Q_0C_1/Q_1$ during normal rainfall years and $\frac{1}{2}[(Q_1 + Q_2) C_2/Q_2 – (C_1 + C_2)]$ during droughts.

Define gross consumer surplus as the area under the demand curve above the price, and net consumer surplus as gross consumer surplus minus (plus) a fixed charge (rebate) for embedded (long run marginal) cost rates, given in Table A1.

Table A1: Gross and Net Consumer Surplus

Weather	Price	Consumer	Gross Consumer Surplus*	Net Consumer Surplus
Normal Year	m	Small	$CS_m^S = ABC$	$S_m^S = CS_m^S – \frac{1}{2}(C_1 + C_2)$
Normal Year	$m + C_1/Q_1$	Small	$CS_1^S = ADE$	$S_1^S = CS_1^S + \frac{1}{2} Q_0 C_1/Q_1$
Normal Year	m	Large	$CS_m^L = ABK$	$S_m^L = CS_m^L – \frac{1}{2}(C_1 + C_2)$
Normal Year	$m + C_1/Q_1$	Large	$CS_1^L = ADM$	$S_1^L = CS_1^L + \frac{1}{2} Q_0 C_1/Q_1$
Drought	m	Small	$CS_m^S = ABC$	$S_m^S = CS_m^S – \frac{1}{2}(C_1 + C_2 + C_3)$
Drought	$m + C_2/Q_2$	Small	$CS_2^S = AFG$	$S_2^S = CS_2^S + \frac{1}{2}[(Q_1 + Q_2) C_2/Q_2 – (C_1 + C_2)]$
Drought	m	Large	$CS_m^L = ABK$	$S_m^L = CS_m^L – \frac{1}{2}(C_1 + C_2 + C_3)$
Drought	$m + C_2/Q_2$	Large	$CS_2^L = AFO$	$S_2^L = CS_2^L + \frac{1}{2}[(Q_1 + Q_2) C_2/Q_2 – (C_1 + C_2)]$

* See Figure A.1.

Small consumer, normal rainfall year, a switch from EC to LMC rates

We can simplify the setup at first by assuming that $Q_0 = 0$. At the lower EC price, m, demand equals supply: $Q_m^S + Q_m^L = Q_1 + Q_2$, and at the higher LMC price $(m + C_1/Q_1)$, demand equals supply: $Q_1^S + Q_1^L = Q_1$. The higher LMC price induces a reduction in quantity demanded from the large and small customers, equal to the output of unit 2:

(A.1) $\Delta Q_1^L = (Q_m^L - Q_1^L)$

(A.2) $\Delta Q_1^S = (Q_m^S - Q_1^S)$

(A.3) $\Delta Q_1^S + \Delta Q_1^L = Q_2$

Therefore, the capital cost of unit 2 can be written:

(A.4) $C_2 = Q_2\, C_2/Q_2 = (\Delta Q_1^S + \Delta Q_1^L)\, C_2/Q_2 = \Delta Q_1^S\, C_2/Q_2 + \Delta Q_1^L\, C_2/Q_2$

= areas CHQR + KLST (see Figure A.1)

$= \Delta Q_1^S\, C_1/Q_1 + \Delta Q_1^S\, (C_2/Q_2 - C_1/Q_1) + \Delta Q_1^L\, C_1/Q_1 + \Delta Q_1^L\, (C_2/Q_2 - C_1/Q_1)$

= areas CHEP + PEQR + KLMU + UMST (see Figure A.1).

Under this simplified setup (Q_0=0), LMC rates collect sufficient revenue from the two customers. To see this, define the percentage of total consumption attributable to the small customer, β,

(A.5) $\beta = Q_1^S/Q_1 = Q_1^S/(Q_1^S + Q_1^L) < ½$,

(A.6) $Q_1^S = \beta Q_1$,

(A.7) $Q_1^L = (1-\beta)Q_1$,

(A.8) $\beta C_1 = Q_1^S\, C_1/Q_1$ = area BHED (see Figure A.1), and

(A.9) $(1- \beta)C_1 = Q_1^L\, C_1/Q_1$ = area BLMD (see Figure A.1).

Total cost equals $(m + C_1/Q_1)\, Q_1$. Revenue collected from the large and small customers, respectively, equals $(1 - \beta)\, Q_1\, (m + C_1/Q_1)$ and $\beta\, Q_1\, (m + C_1/Q_1)$, which when summed equals total cost, so there is no rebate for LMC rates when the price equals $m + C_1/Q_1$. Hence, the terms with Q_0 in Table A1 disappear in this simplified setup (Q_0=0).

Rate reform results in a change in gross consumer surplus, ΔCS_S^N, as follows (see Figure A.1):

(A.10) ΔCS_S^N = ADE – ABC = - BCED = - CHE - BHED = - CHE - βC_1 (see A.8)

The change in net consumer surplus from rate reform is given by ΔS_S^N, as follows:

(A.11) $\Delta S_S^N = - CHE - \beta C_1 + ½\, (C_1 + C_2) = - CHE + (½-\beta)\, C_1 + ½\, C_2$

From the first and third lines of (A.4), we can divide the last term (½ C_2) into three parts,

(A.12) $\Delta S_S^N = - CHE + (½-\beta) C_1 + ½ \Delta Q_1^S C_1/Q_1 + ½ \Delta Q_1^S (C_2/Q_2 - C_1/Q_1) + ½ \Delta Q_1^L C_2/Q_2$

The third term on the right hand side of (A.12), ½ $\Delta Q_1^S C_1/Q_1$, equals the area CHE for linear demand. For non-linear demand, in the limit as ΔQ_1^S goes to zero, the third term equals CHE by the mean value theorem. As an approximation,

(A.13) $\Delta S_S^N \approx (½-\beta) C_1 + ½ \Delta Q_1^S (C_2/Q_2 - C_1/Q_1) + ½ \Delta Q_1^L C_2/Q_2 > 0$

Hence, the change in net consumer surplus for the small consumer is unambiguously positive.

For the original setup where $Q_0 > 0$ (and output from the first unit is lower by this amount), the only change in (A.13) is that the net consumer surplus from rate reform for the small consumer is larger by the rebate:

(A.14) $\Delta S_S^N \approx (½-\beta) C_1 + ½ \Delta Q_1^S (C_2/Q_2 - C_1/Q_1) + ½ \Delta Q_1^L C_2/Q_2 + ½Q_0C_1/Q_1 > 0$

The benefit from rate reform for the small customer, during normal rainfall years, is larger all the smaller the customer (smaller β), all the larger the price elasticity of demand (larger ΔQ_1^S and ΔQ_1^L), all the greater the incremental capital cost of additional supply ($C_2/Q_2 - C_1/Q_1$), and all the larger the supply from rainfall that uses existing system capacity where those capital costs are already paid (Q_0).

Large consumer, normal rainfall year, a switch from EC to LMC rates

For the simplified setup where $Q_0 = 0$, rate reform during normal rainfall years results in a change in gross consumer surplus for the large consumer, ΔCS_L^N, as follows:

(A.15) $\Delta CS_S^N = ADM - ABK = - BKMD = - KLM - Q_1^L C_1/Q_1 = - KLM - (1- \beta) C_1$

The change in net consumer surplus from rate reform is given by ΔS_L^N, as follows:

(A.16) $\Delta S_L^N = - KLM - (1- \beta) C_1 + ½ (C_1 + C_2) = - KLM - (½ - \beta) C_1 + ½ C_2$

and from (A.4) this becomes

(A.17) $\Delta S_L^N = - KLM - (½-\beta) C_1 + ½ \Delta Q_1^S C_2/Q_2 + ½ \Delta Q_1^L C_1/Q_1 + ½ \Delta Q_1^L (C_2/Q_2 - C_1/Q_1)$

The fourth term (½ $\Delta Q_1^L C_1/Q_1$) of (A.17) is approximately equal to area KLM, and we can simplify:

(A.18) $\Delta S_L^N \approx - (½-\beta) C_1 + ½ \Delta Q_1^S C_2/Q_2 + ½ \Delta Q_1^L (C_2/Q_2 - C_1/Q_1)$

Rate reform reduces net surplus to the large customer if

(A.19) $(½-\beta)\ C_1 > ½\ \Delta Q_1^S\ C_2/Q_2 + ½\ \Delta Q_1^L\ (C_2/Q_2 - C_1/Q_1)$

The term on the left hand side is the cross-subsidy of capital costs from the small to the large consumer from the first unit. Hence, all the greater the difference in consumption between the large and small customer (all the smaller β), all the more likely the large customer prefers EC rate design. Dividing through by C_1, all the larger C_1 all the more likely the large customer prefers EC rate design. Additionally, all the more inelastic the small consumer's demand, all the more likely rate reform reduces the large consumer's net surplus.

For the original setup where $Q_0 > 0$, the change in (A.19) is that the net consumer surplus from rate reform for the large consumer is negative if:

(A.20) $(½-\beta)\ Q_1\ C_1/Q_1 > ½\ \Delta Q_1^S\ C_2/Q_2 + ½\ \Delta Q_1^L\ (C_2/Q_2 - C_1/Q_1) + ½Q_0\ C_1/Q_1$

Hence, using already paid capacity to deliver normal rainfall reduces the benefit from EC rate design to the large consumer. As we will see, a drought causes the large consumer to be more favorable to EC rate design.

Small consumer, drought, a switch from EC to LMC rates

Let Q_0 equal the amount lost from the drought, supplied by the third unit when EC rate design sets the price equal to m, so that $Q_1 + Q_2 + Q_3 = Q_m^S + Q_m^L$. With LMC rate design, demand equals supply so that $Q_1 + Q_2 = Q_2^S + Q_2^L$ at the price $m + C_2/Q_2$, inducing a reduction in quantity demanded from the large and small customers, equal to the output of unit 3:

(A.21) $\Delta Q_2^L = (Q_m^L - Q_2^L)$

(A.22) $\Delta Q_2^S = (Q_m^S - Q_2^S)$

(A.23) $\Delta Q_2^S + \Delta Q_2^L = Q_3 = Q_0$

The capital cost of unit 3 can be written:

(A.24) $C_3 = Q_3\ C_3/Q_3 = (\Delta Q_2^S + \Delta Q_2^L)\ C_3/Q_3 = \Delta Q_2^S\ C_3/Q_3 + \Delta Q_2^L\ C_3/Q_3$

= areas VWCI + XYKN (see Figure A.1)

$= \Delta Q_2^S\ C_2/Q_2 + \Delta Q_1^S\ (C_3/Q_3 - C_2/Q_2) + \Delta Q_2^L\ C_2/Q_2 + \Delta Q_2^L\ (C_3/Q_3 - C_2/Q_2)$

= areas CIGR + RGVW + KNOT + TOXY (see Figure A.1).

Define the percentage of total consumption attributable to the small customer, δ,

(A.25) $\delta = Q_2^S/(Q_1 + Q_2) = Q_2^S/(Q_2^S + Q_2^L) < ½$,

(A.26) $Q_2^S = \delta(Q_1 + Q_2)$,

(A.27) $Q_2^L = (1-\delta)(Q_1 + Q_2)$,

(A.28) $Q_2^S C_2/Q_2 = \delta (Q_1 + Q_2) C_2/Q_2$ = area BIGF (see Figure A.1), and

(A.29) $Q_2^L C_2/Q_2 = (1-\delta)(Q_1 + Q_2) C_2/Q_2$ = area BNOF (see Figure A.1).

Rate reform results in a change in gross consumer surplus, ΔCS_S^D, as follows (see Figure A.1):

(A.30) ΔCS_S^D = AFG – ABC = - BCGF = - CIG - BIGF = - CHE - $Q_2^S C_2/Q_2$ (see A.28)

The change in net consumer surplus from rate reform is given by ΔS_S^N, as follows:

(A.31) $\Delta S_S^N = - CHE - Q_2^S C_2/Q_2 + ½ (C_1 + C_2 + C_3) + ½ [(Q_1 + Q_2) C_2/Q_2 – (C_1 + C_2)]$

$= - CHE - \delta (Q_1 + Q_2) C_2/Q_2 + ½ C_3 + ½ (Q_1 + Q_2) C_2/Q_2$

$= - CHE + (½ - \delta)(Q_1 + Q_2) C_2/Q_2 + ½ C_3$

To show that the change in net consumer surplus from rate reform is unambiguously positive for the small consumer, we need only to show that the third term is larger than the first, or $½ C_3 >$ CHE. We can do so in two different ways. One way is to consider the price elasticity of demand for the large and small customers, ε^L and ε^S. For the linear demand curves shown in Figure A.1, at each price $\varepsilon^L = \varepsilon^S$. Define $\alpha = Q_m^S / (Q_m^S + Q_m^L)$. We can easily show that if at each price $\varepsilon^L = \varepsilon^S$, then $\Delta Q_2^S = [\alpha/(1-\alpha)] \Delta Q_2^L$ where $[\alpha/(1-\alpha)] < 1$ because $\alpha < ½$, so that $½ C_3$ is greater than $\Delta Q_2^S C_3/Q_3$ = CIVW > CHE. If $|\varepsilon^S| = \gamma |\varepsilon^L|$ where $\gamma < 1$ as we might expect[24], then $\Delta Q_2^S = \gamma [\alpha/(1-\alpha)] \Delta Q_2^L$, and $½ C_3 >$ CHE.

Alternatively, we can proceed as we did for the small consumer during normal years. From the first and third lines of (A.24), we can divide the last term ($½ C_3$) into three parts, ½ times the sum of areas CIGR + GRWV + KNXY, and recognize that ½ CIGR = $½ \Delta Q_2^S C_2/Q_2 \approx$ CHE.

(A.32) $\Delta S_S^N =$
$- CHE + (½ - \delta)(Q_1 + Q_2) C_2/Q_2 + ½ \Delta Q_2^S C_2/Q_2 + ½ \Delta Q_2^S (C_3/Q_3 - C_2/Q_2) + ½ \Delta Q_2^L C_3/Q_3$

(A.33) $\Delta S_S^N \approx (½ - \delta)(Q_1 + Q_2) C_2/Q_2 + ½ \Delta Q_2^S (C_3/Q_3 - C_2/Q_2) + ½ \Delta Q_2^L C_3/Q_3 > 0$

Hence, the change in net consumer surplus for the small consumer is unambiguously positive.

Large consumer, drought, a switch from EC to LMC rates

Rate reform during a drought results in a change in gross consumer surplus for the large consumer, ΔCS_L^D, as follows:

[24] Large residential consumers have more options to respond to price increases by changing landscaping and purchasing more efficient appliances that smaller consumers may have already done.

(A.34) ΔCS_S^D = AFO - ABK = - BKOF = - KNO - Q_2^L C_2/Q_2

The change in net consumer surplus from rate reform is given by ΔS_L^D, as follows:

(A.35) $\Delta S_L^D = - KNO - Q_2^L\, C_2/Q_2 + ½ (C_1 + C_2 + C_3) + ½ [(Q_1 + Q_2)\, C_2/Q_2 – (C_1 + C_2)]$

$= - KNO - Q_2^L\, C_2/Q_2 + ½\, C_3 + ½ (Q_1 + Q_2)\, C_2/Q_2$

and from (A.27) this becomes

(A.36) $\Delta S_L^N = - KNO - (1-\delta) (Q_1 + Q_2)\, C_2/Q_2 + ½\, C_3 + ½ (Q_1 + Q_2)\, C_2/Q_2$

$= - KNO - (½ -\delta) (Q_1 + Q_2)\, C_2/Q_2 + ½\, C_3$

From (A.24), the last term, ½ C_3 equals ½ times the sum of areas VWCI + XYKN = ½ (VWCI + KNOT + OXYT), where ½ KNOT ≈ KNO. We can simplify (A.36):

(A.37) $\Delta S_L^N \approx - (½ -\delta) (Q_1 + Q_2)\, C_2/Q_2 + ½\, \Delta Q_2^S\, C_3/Q_3 + \Delta Q_2^L\, (C_3/Q_3 – C_2/Q_2)$

Rate reform reduces net surplus to the large customer if

(A.38) $(½ -\delta) (Q_1 + Q_2)\, C_2/Q_2 > ½\, \Delta Q_2^S\, C_3/Q_3 + \Delta Q_2^L\, (C_3/Q_3 – C_2/Q_2)$

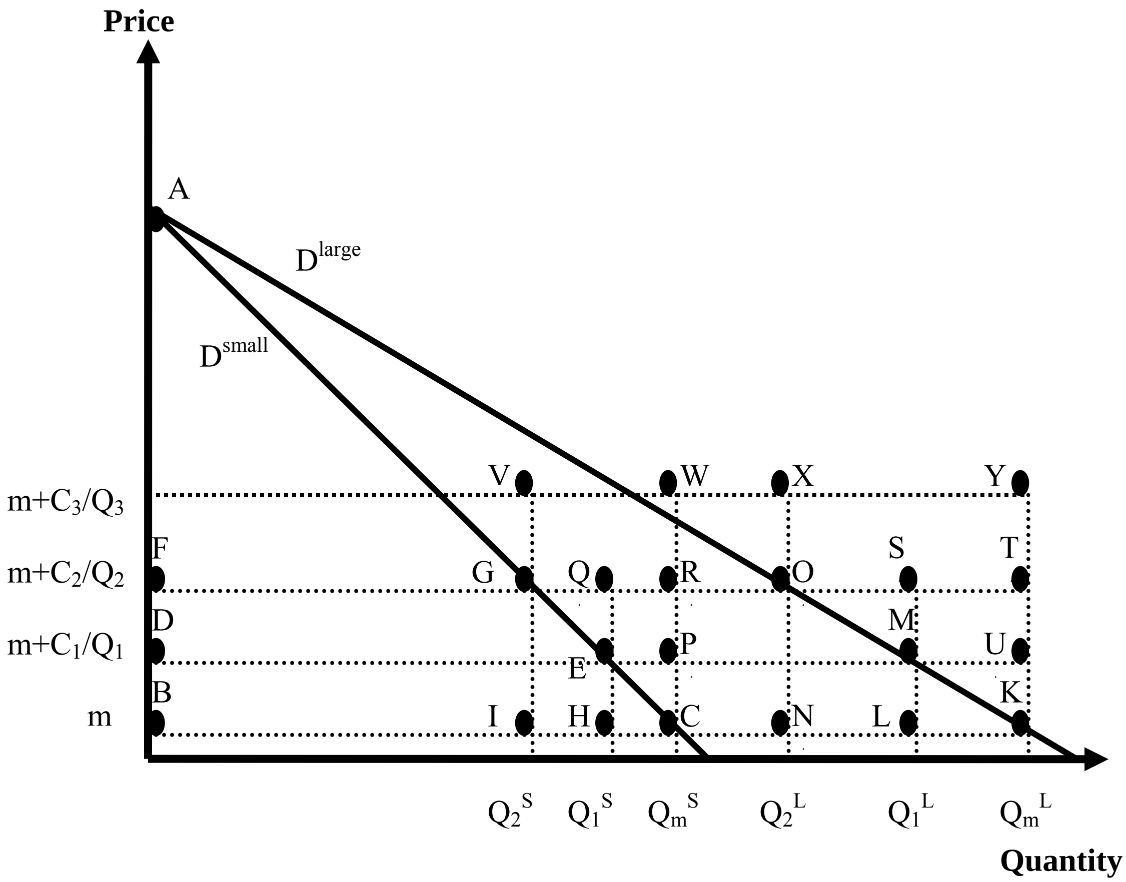
Impact of Drought on Consumer Surplus of Small Relative to Large Consumer

The occurrence of a drought has a relatively large impact from rate reform for the small relative to the large consumer. To see this, we compare equations (A.14) to (A.33) for the small consumer relative to (A.20) to ((A.38) for the large consumer. Recall that $\beta = Q_1^S/Q_1 > \delta = Q_2^S/Q_2$.

Comparing the first term of (A.14) to (A.33), note that $(½-\delta) > (½-\beta)$, $(Q_1+Q_2) > Q_1$, and $C_2/Q_2 > (C_2/Q_2 - C_1/Q_1)$, so the first term in (A.33) is larger than the first term in (A.14). Whether the second term in (A.33) is larger than the second term in (A.14) depends on whether $(C_3/Q_3 - C_2/Q_2) > (C_2/Q_2 - C_1/Q_1)$. For a more severe drought that reduced output from units 1, 2, and 3, and required ever more expensive units to be built, we would expect this to hold. Since $\Delta Q_2^L > \Delta Q_1^L$ and $C_3/Q_3 > C_2/Q_2$, the third term of (A.33) is greater than the third term of (A.14). For a more severe the drought, the difference between (A.33) and (A.14) will increase.

Comparing the left hand sides (A.20) to (A.38), (A.38) is larger. However, for more severe droughts, the left hand side of the inequality in (A.38) increases with the size of a drought, relative to (A.20). For worse droughts, the change in demand due to rate reform increases, and the cost of additional supply also increases. Hence, both the left hand side and right hand side of (A.38) increase, with the consequence that the ambiguity of impact of rate reform on the large consumer's surplus is not resolved with an increase in the severity of a drought.

Figure A.1: Consumer Surplus in Normal Rainfall Years and Droughts



Description: In normal rainfall years, Let $0 < C_1/Q_1 < C_2/Q_2 < C_3/Q_3$ denote increasing incremental per unit capital costs of supplying quantities Q_0, Q_1, Q_2, Q_3, with associated constant short run marginal cost, m, where Q_0 is available during normal rainfall years with zero capital costs and not available during droughts. Define the large consumer as having a greater quantity demanded at every price relative to the small consumer, equal to $Q_m^S < Q_m^L$ when the price is m, $Q_1^S < Q_1^L$ when the price is $m + C_1/Q_1$, $Q_2^S < Q_2^L$ when the price is $m + C_2/Q_2$. During normal rainfall years, let $Q_m^S + Q_m^L = Q_0 + Q_1 + Q_2$, and $Q_1^S + Q_1^L = Q_0 + Q_1$, and during droughts, $Q_0 = 0$, $Q_m^S + Q_m^L = Q_1 + Q_2 + Q_3$ (so $Q_0 = Q_3$), and $Q_1^S + Q_1^L = Q_1 + Q_2$. For a utility with just two consumers, the embedded cost rate design sets the commodity charge equal to m, and the fixed charge for each of the two customers equal to $½ (C_1 + C_2)$ during normal years, and changes the fixed charge during droughts to equal $½ (C_1 + C_2 + C_3)$. The long run marginal cost rate design has a commodity charge equal to $m + C_1/Q_1$ during normal years and $m + C_2/Q_2$ during droughts, with rebates equal to revenue in excess of total costs equal to $½ Q_0 C_1/Q_1$ during normal rainfall years and $½ [(Q_1 + Q_2) C_2/Q_2 – (C_1 + C_2)]$ during droughts. Define gross consumer surplus as the area under the demand curve above the price, net consumer surplus as gross consumer surplus minus (plus) a fixed charge (rebate), and the change in consumer surplus due to rate reform as ΔS_Y^i, where Y = N, D and i = S,L are indexes for normal rainfall years (N), droughts (D), small customer (S) and large customer (L). The change in consumer surplus from rate reform equals: $\Delta S_N^S = - CDE + ½ Q_0 C_1/Q_1 + ½ (C_1 + C_2)$, $\Delta S_D^S = - CFG + ½ Q_1 C_2/Q_2 + ½ (C_1 + C_2 + C_3)$, $\Delta S_N^L = IAK - ½ Q_0 C_1/Q_1 - ½ (C_1 + C_2)$, $\Delta S_N^L = ILM - ½ Q_1 C_2/Q_2 - ½ (C_1 + C_2 + C_3)$ (see the appendix).