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Comparing price and nonprice approaches to urban water conservation

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[1] Urban water conservation is typically achieved through prescriptive regulations, including the rationing of water for particular uses and requirements for the installation of particular technologies. A significant shift has occurred in pollution control regulations toward market-based policies in recent decades. We offer an analysis of the relative merits of market-based and prescriptive approaches to water conservation, where prices have rarely been used to allocate scarce supplies. The analysis emphasizes the emerging theoretical and empirical evidence that using prices to manage water demand is more cost effective than implementing nonprice conservation programs, similar to results for pollution control in earlier decades. Price-based approaches may also compare favorably to prescriptive approaches in terms of monitoring and enforcement. Neither policy instrument has an inherent advantage over the other in terms of predictability and equity. As in any policy context, political considerations are also important.

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1. Introduction

[2] Cities around the world struggle to manage water resources in the face of population increases, consumer demand for water-intensive services, and increasing costs (including environmental costs) of developing new supplies. In this paper, we provide an economic perspective on reducing urban water demand through pricing and nonprice conservation policies. We compare price and nonprice approaches along five dimensions: the ability of policies to achieve water conservation goals, cost effectiveness, distributional equity, monitoring and enforcement, and political feasibility.

[3] Municipal water consumption comprises only about 12% of total freshwater withdrawals in the United States, and agricultural irrigation, the single largest water use, comprises just over one third of all withdrawals [*Hutson et al.*, 2004]. While analysis suggests that reallocating water from agriculture to cities would be efficient in many regions, in the current legal and political setting, large-scale transfers of water rights from agriculture to cities are uncommon [*Brewer et al.*, 2007; *Brown*, 2006; *Howe*, 1997]. Thus, cities often must reduce water consumption during acute shortages due to drought, or in the long run because of constraints on their ability to increase supply.

[4] The efficient water price is the long-run marginal cost (LRMC) of supply in most cases, though in some cases charging short-run marginal cost may be efficient [*Russell and Shin*, 1996a]. LRMC reflects the full economic cost of water supply: the cost of transmission, treatment and distribution; some portion of the capital cost of current reservoirs and treatment systems, as well as those future facilities necessitated by current patterns of use; and the opportunity cost in both use and nonuse value of water for other potential purposes. Urban water prices lie well below LRMC in many countries [*Sibly*, 2006; *Timmins*, 2003; *Renzetti*, 1999; *Munasinghe*, 1992], with significant economic costs [*Renzetti*, 1992b; *Russell and Shin*, 1996b]. In the short run, without price increases acting as a signal, water consumption proceeds during periods of scarcity at a faster-than-efficient pace. Water conservation takes place only under ‘‘moral suasion or direct regulation’’ [*Gibbons*, 1986, p. 21]. In contrast, if water prices rose as reservoir levels fell, consumers would respond by using less water, reducing or eliminating uses according to their preferences. In the long run, inefficient prices alter land use patterns and industrial location decisions. The sum of all these individual decisions affects the sustainability of local and regional water resources.

[5] Implementation of efficient water prices would be challenging. Some of the opportunity costs of urban water supply are difficult to quantify. What is the value of a gallon of water left in stream to support endangered species habitat, for example? While economists have developed a variety of useful methods for estimating such values, the expectation that every water supplier will develop measures of the LRMC of water supply, including the opportunity cost of leaving water in stream, is unrealistic. This is complicated by the known problems with so-called ‘‘benefit transfer,’’ the practice of using resource values estimated for one ecosystem in other locations. LRMC represents a critical water pricing goal, but it is not the focus of this paper. There are smaller, less ambitious steps toward efficiency that may be accomplished more readily.

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[6] Various policies can be employed to achieve the conservation of a particular quantity of water, some more costly than others. Here we use water conservation in its familiar meaning, rather that an economic definition, which would require true conservation of resources (with benefits exceeding costs) [*Baumann et al.*, 1984]. Choosing the least costly method of achieving a water conservation goal is characterized in economic terms as cost-effective water management. Even if the goal is inefficient, society can benefit from the minimization of costs to achieve it.

[7] We focus on this issue of policy instrument choice for water conservation, summarizing research from the economics literature. Given the strong theoretical cost advantages of market-based approaches to water conservation over conventional alternatives, and the emerging empirical evidence for the potential cost savings from moving to market-based approaches, the time is ripe for a discussion of the relative strengths and weaknesses of these policy instruments.

2. Cost Effectiveness of Water Conservation Policies

[8] Decades of theoretical and empirical economic analysis suggest that market-based environmental policies are more cost effective than conventional policies, often characterized as prescriptive or command-and-control (CAC) approaches. Market-based regulations encourage behavior through market signals rather than through explicit directives to individual households and firms regarding conservation levels or methods. These policy instruments set an aggregate standard and allow firms and households to undertake conservation efforts that are in their own interests and collectively meet the aggregate standard. CAC approaches, in contrast, allow less flexibility in the means of achieving goals and often require households or firms to undertake similar shares of a conservation burden regardless of cost. Some CAC approaches to environmental policy are more cost effective than others, and the more flexible CAC approaches may compare favorably with market approaches in some cases. In water conservation, however, the most common CAC approaches are rationing (e.g., outdoor watering restrictions) in the short run, and technology standards (e.g., low-flow fixture requirements) in the long run. Both approaches are among the least flexible of CAC policies, and both can be expected to generate significant economic losses.

[9] In the area of pollution control, the cost-effectiveness advantage of market-based approaches over CAC policies has been demonstrated theoretically [*Pigou*, 1920; *Crocker*, 1966; *Dales*, 1968; *Montgomery*, 1972; *Baumol and Oates*, 1988] and empirically [*Keohane*, 2007; *Teitenberg*, 2006]. The best known application of these principles to environmental regulation is the U.S. SO_2 trading program, established under Title IV of the Clean Air Act Amendments of 1990, which has produced cost savings on the order of $1 billion annually [*Stavins*, 2003]. Dozens of other market-based policies have been applied to air and water pollution control, fisheries management, and other environmental problems in industrialized and developing countries [*Kolstad and Freeman*, 2007; *Stavins*, 2003; *Sterner*, 2003; *Panayotou*, 1998].

[10] Economists have only recently begun to measure the potential economic gains from adopting market-based approaches to water conservation. Recent studies demonstrate how raising prices, rather than implementing nonprice policies, can substantially reduce the economic cost of achieving water consumption reductions in theory. *Collinge* [1994] proposes a municipal water entitlement transfer system and demonstrates that this can reduce costs significantly over a CAC approach. An experimental study simulates water consumption from a common pool and predicts that consumer heterogeneity generates economic losses from CAC water conservation policies [*Krause et al.*, 2003]. *Brennan et al.* [2007] construct a household production model that suggests efficiency losses will result from outdoor watering restrictions.

[11] To illustrate the basic economics, we examine one typical CAC approach to water conservation, a citywide restriction on outdoor uses, uniform across households. Figure 1 portrays two households with the same indoor demand curves, but different preferences for outdoor water use. The difference in slopes of the three demand curves is associated with differences in elasticity, the percentage drop in demand prompted by a one percent price increase. (For all but one specific class of demand function, price elasticity varies along the demand curve, thus while we can speak broadly about comparisons across demand curves, there are points on a relatively steep demand curve at which price elasticity exceeds that on some parts of a flat demand curve.) Here we assume that indoor demand (Figure 1c), the steepest curve, is inelastic, because indoor uses are less easily reduced in response to price changes, reflecting the basic needs met by indoor water use. For outdoor demand, there is a relatively elastic household (Figure 1a), and a somewhat less elastic household (Figure 1b). Household A will reduce outdoor demand relatively more in response to a price increase, perhaps because it has weaker preferences for outdoor consumption (e.g., in the short run, it would rather allow the lawn to turn brown than pay a higher water bill to keep it green).

[12] Unregulated, at price $\bar{P}$, both households consume Q_C water indoors, household B consumes Q_B^{unreg} outdoors, and household A consumes Q_A^{unreg} outdoors. The outdoor reduction mandated under a CAC approach (which leaves indoor use unchanged, and reduces outdoor uses to Q_B^{reg} and Q_A^{reg}) creates a "shadow price" for outdoor consumption (λ) that is higher under the current marginal price ($\bar{P}$) for household B than for A, because household B is willing to pay more than A for an additional unit of water. If instead the water supplier charges price P^*, that achieves the same aggregate level of water conservation as the CAC approach, consumers would realize all potential gains from substitution within and across households, erasing the shaded deadweight loss triangles. Consumption moves to Q_C^* indoors for both types of households, and to Q_A^* and Q_B^* outdoors. The savings from the market-based approach are driven by two factors: (1) the ability of households facing higher prices rather than quantity restrictions to decide which uses to reduce according to their own preferences and (2) allowing heterogeneous responses to the regulation across households, resulting in substitution of scarce water from those households who value it less, to those who value it more.

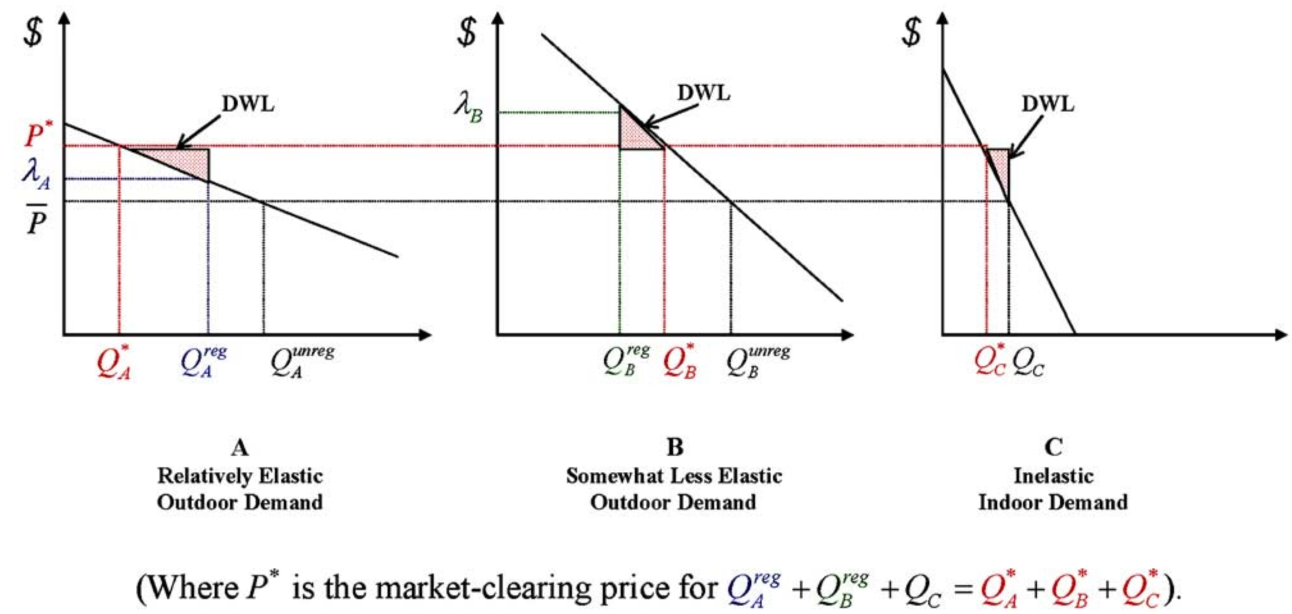

Figure 1. Economic losses from outdoor consumption restrictions with heterogeneous outdoor demand: (a) relatively elastic outdoor demand, (b) somewhat less elastic outdoor demand, and (c) inelastic indoor demand.

[13] Rationing approaches to water conservation are ubiquitous. During a 1987–1992 drought in California, 65–80% of urban water utilities implemented outdoor watering restrictions [*Dixon et al.*, 1996]. In 2008, 75% of Australians live in communities with some form of mandatory water use restrictions [*Grafton and Ward*, 2008]. Long-run water conservation policies are often technology standards. Since 1992, the National Energy Policy Act has required that all new U.S. construction install low-flow toilets, showerheads, and faucets. Many municipal ordinances mandate technology standards more stringent than the national standards [*U.S. General Accounting Office*, 2000].

[14] How large are the losses from nonprice demand management approaches? Four analyses have estimated the economic losses from CAC water conservation policies. *Timmins* [2003] compared a mandatory low-flow appliance regulation with a modest water price increase, using data from 13 groundwater-dependent California cities. Under all but the least realistic of assumptions, he found prices to be more cost effective than technology standards in reducing groundwater aquifer lift height in the long run.

[15] A study of 11 urban areas in the United States and Canada compared residential outdoor watering restrictions with drought pricing in the short run [*Mansur and Olmstead*, 2007]. For the same aggregate demand reduction as that implied by a 2-day-per-week outdoor watering restriction, a market-clearing price would result in gains of about \$81 per household per summer, about one quarter of the average household's total annual water bill in the study. *Brennan et al.* [2007] arrived at similar short-run conclusions; the economic costs of a 2-day-per-week sprinkling restriction in Perth, Australia are just under \$100 per household per season, and the costs of a complete outdoor watering ban range from \$347 to \$870 per household per season. (Under the sprinkling restriction, watering by hand was allowed, so the policy was a technology standard.) Mandatory water restrictions in Sydney, Australia over a single year in 2004–2005 resulted in economic losses of \$235 million, or about \$150 per household, about one half the average Sydney household water bill in that year [*Grafton and Ward*, 2008].

[16] On the basis of both economic theory and the emerging empirical estimates, the inescapable conclusion is that using price increases to reduce demand, allowing consumers to adjust their end uses of water, is more cost effective than implementing nonprice demand management programs. This holds true empirically in both the short and the long run. In the long run, price increases provide stronger incentives for the development and adoption of new water conservation technologies, since households and firms stand to save more on water costs from adopting such technologies when water is more expensive. With higher prices, water users choose the technology that provides the desired level of water conservation, given their preferences or production technologies, in return for the lowest investment cost. Technology standards can actually dampen incentives to innovate, locking in whatever is state-of-the-art when the standard is passed. This is an effect that is well documented for pollution control regulations [*Downing and White*, 1986; *Milliman and Prince*, 1989; *Keohane*, 2005], but has not been considered in the literature on water conservation.

3. Predictability in Achieving Water Conservation Goals

3.1. Effects of Price on Water Demand

[17] If policymakers are to use prices to manage demand, the key variable of interest is the price elasticity of water demand. An increase in the water price leads consumers to use less of it, all else equal, so price elasticity is a negative number. An important benchmark elasticity is -1.0; this

threshold divides demand into the categories of elastic and inelastic. There is a critical distinction between "inelastic demand" and demand which is "unresponsive to price." If demand is truly unresponsive to price, price elasticity is equal to zero, and the demand curve is a vertical line, the same quantity of water will be demanded at any price. This may be true for a subsistence quantity of drinking water, but it has not been observed for urban water demand more broadly in 50 years of empirical economic analysis.

[18] Residential water demand is inelastic at current prices. In a meta-analysis of 124 estimates generated between 1963 and 1993, accounting for the precision of estimates, *Espey et al.* [1997] obtained an average price elasticity of −0.51, a short-run median estimate of −0.38, and a long-run median estimate of −0.64. Likewise, *Dalhuisen et al.* [2003] obtained a mean price elasticity of −0.41 in a meta-analysis of almost 300 price elasticity studies, 1963–1998. The price elasticity of residential water demand varies across place and time, but on average, in the United States, a 10% increase in the marginal price of water in the urban residential sector can be expected to diminish demand by about 3–4% in the short run. This is similar to empirical estimates of the price elasticity of residential energy demand [*Bohi and Zimmerman*, 1984; *Bernstein and Griffin*, 2005]. With an elasticity of −0.4, if a water utility wanted to reduce demand by 20% (not an uncommon goal during a drought), this could require approximately a 50% increase in the marginal water price.

[19] Industrial price elasticity estimates for water tend to be higher than residential estimates and vary by industry. The literature contains only a handful of industrial elasticity estimates. The results of five studies, 1969–1992, are reported by *Griffin* [2006], ranging from −0.15 for some two-digit SIC codes [*Renzetti*, 1992a], to −0.98 for the chemical manufacturing industry [*Ziegler and Bell*, 1984]. A study of 51 French industrial facilities estimates an average demand elasticity of −0.29 for piped water, with a range of −0.10 to −0.79, depending on industry type [*Reynaud*, 2003].

[20] There are some important caveats worth mentioning. First, any estimate represents an elasticity in a specific range of prices. Were prices to approach the efficient levels discussed earlier, water demand would likely be much more sensitive to price increases. Second, consumers and firms are relatively more sensitive to water prices in the long run than in the short run, because in the long run capital investments are not fixed. Households might replace appliances, retrofit water-using fixtures, or landscape with drought-tolerant plants; firms may change water-consuming technologies, increase recycling, or relocate to areas in which water is more plentiful. In the long run, a 10% price increase can be expected to decrease residential demand by about 6%, almost twice the average short-run response [*Espey et al.*, 1997].

[21] Third, price elasticities vary with many other factors. In the residential sector, high-income households tend to be much less sensitive to water price increases than low-income households. Similarly, industrial water demand elasticity is higher for industries in which the cost share of water inputs is larger [*Reynaud*, 2003]. Price elasticity may increase when price information is posted on water bills [*Gaudin*, 2006], and it may be higher under increasing-block tariffs (in which the marginal volumetric water price increases with consumption) than under uniform volumetric prices [*Olmstead et al.*, 2007]. Price elasticities must be interpreted in the context in which they have been derived, thus, for the impact of a price increase to achieve a predictable demand reduction, individual utilities must estimate a price elasticity for their own current customer base.

[22] If water suppliers seek to reduce demand in the long run by raising prices, a price elasticity for their customer base may be all that they need to achieve predictability. To generate such an estimate for the residential sector, they would need, at a minimum, detailed data on water consumption, household income, and marginal water prices over a period in which prices have varied sufficiently to allow the estimation of the relationship between price and demand. An even better estimate would require data on weather, as well as household characteristics that serve as proxies for water consumption preferences, things like the size of families, homes, and lots. Estimating industrial elasticities is much more complicated [*Renzetti*, 2002]; with few industrial estimates in the literature, this is an important focus for future research in the economics of urban water conservation.

[23] Reducing demand through pricing in the short run may require additional detail. For example, seasonal elasticities are useful if utilities want to use prices to reduce peak summer demand. If prices are to be increased on subsets of the full customer base, then elasticities for those particular classes of households or industries must be estimated in order to achieve the desired demand impact. Needless to say, where water consumption is not metered, price cannot be used to induce water conservation. Where information on water consumption, prices, income and other factors is insufficient to estimate a local elasticity, price may still be used as a water conservation policy (perhaps using elasticity estimates from the literature as a guide), but with unpredictable results.

3.2. Effects of Nonprice Conservation Programs on Water Demand

[24] Historically, water suppliers have relied on nonprice conservation programs to induce demand reductions during shortages. We consider the effects of such nonprice programs in three categories: (1) required or voluntary adoption of water-conserving technologies, (2) mandatory water use restrictions, and (3) mixed nonprice conservation programs. These policies have primarily targeted residential customers, so this is the focus of our discussion.

3.2.1. Water-Conserving Technology Standards

[25] When the water savings from technology standards have been estimated, they have often been smaller than expected because of behavioral changes that partially offset the benefit of greater technical efficiency. For example, households with low-flow showerheads may take longer showers [*Mayer et al.*, 1998]. The "double flush" was a notorious difficulty with early models of low-flow toilets. In a recent field trial, randomly selected households had their top-loading clothes washers replaced with front-loading models. The average front-loading household increased clothes washing by 5.6%, perhaps because of the cost savings associated with increased efficiency [*Davis*,

2008]. This "rebound effect" has been demonstrated for energy demand, as well [*Greening et al.*, 2000].

[26] Several engineering studies have observed a small number of households in a single region to estimate the water savings associated with low-flow fixtures. One study indicates that households fully constructed or retrofitted with low-flow toilets used about 20 percent less water than households with no low-flow toilets. The equivalent savings reported for low-flow showerheads was 9 percent [*Mayer et al.*, 1998]. Careful studies of low-flow showerhead retrofit programs in the East Bay Municipal Utility District, California, and Tampa, Florida estimate water savings of 1.7 and 3.6 gallons per capita per day (gpcpd), respectively [*Aher et al.*, 1991; D. L. Anderson et al., The impact of water conserving fixtures on residential water use characteristics in Tampa, Florida, paper presented at Conserv93, American Water Works Association, Las Vegas, Nevada, 1993]. In contrast, showerhead replacement had no statistically significant effect in Boulder, Colorado [*Aquacraft Water Engineering and Management*, 1996]. Savings reported for low-flow toilet installation and rebate programs range from 6.1 gpcpd in Tampa, Florida to 10.6 gpcpd in Seattle, Washington [*U.S. General Accounting Office*, 2000]. *Renwick and Green* [2000] estimate no significant effect of ultra low-flush toilet rebates in Santa Barbara, California.

3.2.2. Mandatory Water Use Restrictions

[27] Mandatory water use restrictions may limit the total quantity of water that can be used or restrict particular water uses. Empirical evidence regarding the effects of these programs is mixed. Summer 1996 water consumption restrictions in Corpus Christi, Texas, including prohibitions on landscape irrigation and car washing, did not prompt statistically significant water savings in the residential sector [*Schultz et al.*, 1997]. A longer-term program in Pasadena, California resulted in aggregate water savings [*Kiefer et al.*, 1993], as did a program of mandatory water use restrictions in Santa Barbara, California [*Renwick and Green*, 2000].

3.2.3. Mixed Nonprice Conservation Programs

[28] Water utilities often implement multiple nonprice conservation programs simultaneously. One analysis of the effect of conservation programs on aggregate water district consumption in California found small but significant reductions in total water use attributable to landscape education programs and watering restrictions, but no effect due to indoor conservation education programs, low-flow fixture distribution, or the presentation of conservation information on customer bills [*Corral*, 1997]. The number of conservation programs in place in California cities may have a small negative impact on total residential water demand [*Michelsen et al.*, 1998]. Public information campaigns, retrofit subsidies, water rationing, and water use restrictions had negative and statistically significant impacts on average monthly residential water use in California, and the more stringent policies had stronger effects than voluntary policies and education programs [*Renwick and Green*, 2000].

3.2.4. Summing up the Predictability Comparison

[29] Predictability of the effects of a water conservation policy may be of considerable importance to water suppliers. If certainty over the quantity of conservation to be achieved is required, economic theory would suggest that quantity restrictions are preferred to price increases. A price-based approach, in contrast, provides greater certainty over compliance costs [*Weitzman*, 1974]. However, this assumes that suppliers can rely on compliance with quantity-based restrictions. In a comprehensive study of drought management policies among 85 urban water utilities during a prolonged drought in southern California, 40 agencies adopted mandatory quantity restrictions, but that more than half of customers violated restrictions [*Dixon et al.*, 1996]. Such nonbinding quantity constraints are common. In the same study, about three quarters of participating urban water agencies implemented type-of-use restrictions (most of them mandatory). Few penalties were reported, and enforcement was weak, again raising questions regarding compliance. Neither price nor nonprice demand management programs have an advantage in terms of predicting water demand reductions. For each type of policy, the key to predictability is the existence of high-quality, current statistical estimates of the impacts of similar measures (price increases or nonprice policies), for a utility's own customers.

4. Equity and Distributional Considerations

[30] The main distributional concern with a market-based approach to urban water management arises from the central feature of a market: allocation of a scarce good by willingness to pay (WTP). Under some conditions, WTP may be considered an unjust allocation criterion. The sense that some goods and services should not be distributed by markets in particular contexts explains the practice of wartime rationing, for example. A portion of water in residential consumption is used for basic needs, such as drinking and bathing. "Lifeline" rates and other accommodations ensuring that water bills are not unduly burdensome for low-income households are common. Thus, policymakers considering market-based approaches to water management must be concerned about equity in policy design.

[31] What does economic theory tell us about the equity implications of water pricing as a conservation tool? If water demand management occurs solely through price increases, low-income households will contribute a greater fraction of a city's aggregate water savings than high-income households, in part because price elasticity declines with the fraction of household income spent on a particular good. The empirical evidence supports this conclusion. *Agthe and Billings* [1987] found that low-income households exhibited a larger demand response to price increases in Tucson, Arizona. *Renwick and Archibald* [1998] found that low-income households in southern California communities were more price responsive than high-income households. *Mansur and Olmstead* [2007] found that raising prices to reduce consumption would cause a greater consumption reduction for low-income than for high-income households.

[32] The fact that price-based approaches reduce water consumption more among poor households than rich ones does not mean these policies are regressive, or conversely that nonprice policies are progressive. Some nonprice policies are clearly progressive. For example, a landscape irrigation technology standard imposes costs mainly among high-income households [*Renwick and Archibald*, 1998]. But the distributional impact of most nonprice programs

depends on how they are financed. And progressive price-based approaches to water demand management can be designed by returning utility profits (from higher prices) in the form of rebates. In the case of residential water users, this could occur through the utility billing process.

[33] Drought pricing, like LRMC pricing, would cause utilities to earn substantial short-run profits. In the case of LRMC pricing, short-run profits are earned because LRMC is increasing; suppliers tap the cheapest supplies first (e.g., those closest geographically to the cities they serve) [*Hanemann*, 1997]. With drought pricing, price increases reflecting scarcity reduce demand, but because demand is inelastic, total revenues increase. Water utilities' rate of return is typically regulated. The increase in revenues from drought pricing may drive rates of return above regulated maximums. Such profits could be avoided if water managers implemented household-level trading through a centralized credit market managed by the water utility, as proposed by *Collinge* [1994], although transaction costs in this approach may be high. With drought pricing, profits could be reallocated on the basis of any measure that is not tied to current consumption. Such a rebate policy would retain the strong economic incentive benefits of drought pricing relative to CAC approaches, without imposing excessive burdens on low-income households [*Mansur and Olmstead*, 2007]. A rebate based on a household's consumption is equivalent to changing the price and will work against the price increase's impact. A rebate that works, instead, like a negative fixed charge will increase a household's income without changing the price signal that the household faces each time it turns on the tap. Since demand is a function of income, as well as prices, a rebate that significantly increased household income might erase a small portion of the conservation achieved with a price increase, but this is unlikely to be a significant factor for households in industrialized countries, where annual water bills comprise a tiny fraction of household income.

5. Monitoring and Enforcement

[34] In some cases, the monitoring and enforcement costs of market-based approaches to environmental policy can exceed those of CAC policies; how the two classes of policy instrument compare on this dimension depends on many factors [*Keohane and Olmstead*, 2007]. But in the particular case of metered municipal water consumption, we would expect the costs of monitoring and enforcing compliance with price increases to compare favorably to those for rationing and technology standards.

[35] The difficulty in monitoring and enforcing rationing and technology standards is one reason outdoor watering restrictions are common; outdoor uses are visible, and it is relatively easy to cruise residential streets searching for violators. Even so, as we point out in section 3.2.4, compliance with outdoor water rationing policies may be low. Monitoring and enforcement challenges may also explain noncompliance with indoor water conservation technology standards. Where low-flow fixtures are encouraged or required, they are often replaced with their higher-flow alternatives if consumers are dissatisfied with performance. One analysis suggests that 6% of low-flow showerheads in a Pacific Gas and Electric replacement program were either removed or not used, that showerheads advertised on the Internet in 2005 include systems supplying up to 10 gallons per minute (gpm), when the Federal standard has been 2.5 gpm since 1992, and that so-called "cascading" showerhead systems had a market share of 15% in 2004 [*Biermayer*, 2005]. Consumers were dissatisfied with early models of low-flow toilets, and a black market arose in the older models. In September 2008, a search on eBay turns up dozens of 3.5-gallon toilets, technically illegal to install in new U.S. construction since 1992 (see ww.ebay.com and search "3.5 toilet"). Achieving full compliance with regulations that restrict consumers' in-home behavior (and in some of their most private activities) is a significant challenge.

[36] In contrast, noncompliance in the case of pricing requires that households consume water "off meter," since water consumption is metered and billed volumetrically in most U.S. cities. Of course, higher prices generate incentives for avoidance as well as conservation. However, at prevailing prices the monitoring and enforcement costs of price changes are likely to compare favorably to the current CAC approach.

6. Political Considerations

[37] Water demand management through nonprice techniques is the overwhelmingly dominant paradigm in cities around the world. Raising prices can be politically difficult. After a 2-year drought in the late 1970s, the city of Tucson, Arizona was the first U.S. city to adopt marginal cost water prices, which involved a substantial increase. One year later, the entire Tucson city council was voted out of office because of the water rate increase [*Hall*, 2000]. Just as few elected officials relish the prospect of raising taxes, few want to increase water rates.

[38] Ironically, nonprice programs are more expensive to society than water price increases, once the real costs of policies and associated economic losses are considered. A parallel can be drawn in this case to market-based approaches to environmental pollution control. Cost effectiveness has only recently been accepted as an important criterion for the selection of policies to control pollution. Given the empirical evidence regarding their higher costs, how can we explain the persistence of CAC approaches? Some resistance to using prices may be due to misinformation, since most policymakers and water customers are not aware of the cost-effectiveness advantage of the price-based approach. For example, a common misconception in this regard is that price elasticity is "too low to make a difference." In this case, economists might make a better effort to communicate the results of demand studies, as we attempt to do here.

[39] The prevalence of subsidized water prices in the short and the long run may also be an example of the common phenomenon of "fiscal illusion." Households may object more strongly to water price increases than to increases in less visible sources of revenue (e.g., local tax bills) that municipalities may use to finance a subsidy. *Timmins* [2002] demonstrates that the more skewed the income distribution among consumers, the heavier the observed discount in water prices, suggesting that those who set water prices may use the process to achieve distributional goals at the cost of efficiency. The prevalence of CAC water conservation policies may be a result of

traditional interest group politics, in which political constituencies that prefer CAC approaches succeed in preventing the introduction of market-based approaches [*Rausser*, 2000; *Hall*, 2000]. *Hewitt* [2000] provides empirical evidence that a utility's propensity to adopt ''market-mimicking'' water prices may have to do with administrative sophistication, system ownership (public or private), and financial health.

[40] The literature contains few theoretical discussions of this issue, and even fewer empirical studies. Similar questions have been debated over the dominance of costly CAC policies for pollution control. Economists have modeled the eventual introduction of market approaches as a result of demand by regulated firms, consumers, labor and environmental groups, supply by legislators and other decision makers, or some combination of these forces [*Keohane et al.*, 1998]. There may be a clear parallel with CAC versus market-based approaches to water conservation. But does the model need to change in order to accommodate the fact that such policies are usually set locally and regionally, while pollution control policies tend to be national in scope? The relative incentives of the regulated community (primarily consumers in this case, rather than firms, as in the pollution control case) are also likely quite different. The political economy of water conservation policy instrument choice is an important area for further research.

[41] In pollution control, the adoption of market-based approaches has been supported by some environmental advocacy groups, who realized that greater pollution reductions might be achieved for the same cost if governments switched from CAC to market approaches [*Keohane et al.*, 1998]. Perhaps a similar shift is possible in water conservation policy. There is another aspect of the water conservation context which suggests that consumers, themselves, may be convinced of the benefits of market approaches. Nonprice demand management techniques can create political liabilities in the form of water utility budget deficits, because these policies require expenditures, and if they succeed in reducing demand, they reduce revenues. During prolonged droughts, these combined effects can result in the necessity for price increases following ''successful'' nonprice conservation programs, to protect utilities from unsustainable financial losses. During a prolonged drought, Los Angeles water consumers responded to their utility's request for voluntary water use reductions. Total use and total revenues fell by more than 20 percent. The utility then requested a rate increase to cover its growing losses [*Hall*, 2000]. In contrast, given common U.S. urban price elasticities, price increases will increase water suppliers' total revenues. The extra per-unit revenues from a price increase outweigh lost revenue from falling demand. It may be advantageous for water managers to explain this carefully to consumers: you can face an increased price now, and choose how you will reduce consumption; or you can comply with our choices for reducing your consumption now, and pay increased prices later.

[42] The relative advantages of price over nonprice water demand management policies are clear. But like other subsidies, low water prices (on a day-to-day basis, as well as during periods of drought) are popular and politically difficult to change. Some communities may be willing to continue to bear excessive costs from inefficient water pricing, in exchange for the political popularity of low prices. Continuing to quantify and communicate the costs of these tradeoffs is an important priority for future research.

7. Concurrent Use of Market-Based and CAC Approaches

[43] Thus far, we have compared and contrasted CAC approaches with market-based policies, yet in many cases, solutions to environmental problems in the real world may include combinations of these policies. *Bennear and Stavins* [2007] identify two common contexts in which the concurrent use of CAC and market-based approaches may be economically justified: where multiple market failures exist, only some of which can be corrected; and where exogenous political or legal constraints cannot be removed.

[44] Water conservation policy offers a clear case of the second circumstance in some municipalities. Raising water prices may be efficient but politically unacceptable to particular constituencies. In other cases, rate-setting officials may be constrained by law, unable to increase water prices by a percentage that exceeds some statutory maximum, or in a time frame that makes prices viable short-run policy levers during a drought. Price setting is a political process for most water supply institutions, not one they can control easily. This may be exacerbated by long billing periods. If a reduction in water consumption is required in the very short run, for example, in the middle of a dry July, but many households and businesses will not be billed until September, consumers' awareness of the price increase may come too late to have the desired short-run impact. (While such a short-run effect is certainly possible, research suggests that price elasticity is insensitive to billing frequency in the long run [*Gaudin*, 2006; *Kulshreshtha*, 1996].) This problem might be alleviated by providing consumers with clear information about price changes immediately (e.g., through public service announcements), or by more frequent billing. The implications of political and legal constraints for the relative efficiency of market-based and CAC approaches is an important topic for future research in the economics of water conservation.

[45] Some aspects of the current CAC approaches may also be retained when market approaches are introduced in an effort to make municipal water supply and conservation more equitable. This is typical of many environmental policy situations in which market approaches have been applied [*Bennear and Stavins*, 2007]. In the case of water pricing, one such effort is the use of increasing-block tariffs (IBTs), in which a low marginal price is charged for water consumption up to some threshold, and consumption above the threshold is priced at a much higher volumetric rate, in some cases even approaching the LRMC of water supply [*Olmstead et al.*, 2007]. The equity aspects of IBT structures have many dimensions; the first ''block'' quantity of water is made available to all households at the same low price and can be assumed to cover, at a minimum, basic needs like drinking and bathing; those paying the higher-tier price on the margin may be higher-income consumers, primarily households using water outdoors; and the two- (or more) tier price system allows utilities to meet rate-of-return constraints without a rebate system, which might require means testing to achieve any distributional goal.

[46] There are two things to note about IBTs and other combinations of CAC and market-based approaches to water conservation. First, some of the efficiency gains of the market-based approach are lost when these kinds of constraints are imposed. In the case of IBTs, consumers in different blocks face different marginal prices when they choose to turn on the tap or the sprinkler system. The economic losses from this may be quantified (though they have not, to our knowledge, an interesting area for further research). So any distributional advantage is purchased when pairing CAC and market approaches; it does not come for free. This may be fine; efficiency is one of many important goals in setting water prices and conservation policy, and some tradeoffs are inevitable.

[47] But this brings us to our second point about retaining some costly prescriptive policies in order to make market approaches more equitable; it is, at least in theory, unnecessary. Take the case of IBTs. An efficient pricing regime would simply charge the LRMC of supply for all units of water purchased by all consumers, and rebate any excess utility revenues to consumers. Such a system is described in detail by *Boland and Whittington* [2000]. A similar application different from IBTs, moving from water rationing to drought pricing, is described by *Mansur and Olmstead* [2007]. Given the potentially large economic costs of maintaining CAC water conservation policies, even partially, and the desirability of equitable allocation mechanisms for water, the design of market-based water conservation approaches that are explicitly (and not just potentially) progressive is a critical area for future research.

8. Conclusions

[48] Using prices to manage water demand is more cost effective than implementing nonprice conservation programs. The gains from using prices as an incentive for conservation come from allowing households to respond to increased water prices in the manner of their choice, rather than installing a mandated technology or reducing specified uses. The theoretical basis for this point is very strong and was established in the economics of pollution control many decades ago. A handful of papers have now established the parallel theory for water conservation, and statistical studies have generated empirical estimates of the potential economic gains from a shift from technology standards and rationing to market-based approaches. While we anticipate that the results of this type of research will continue to raise new questions, the emerging evidence suggests that cities would do well to switch from CAC to price-based water conservation, in terms of cost effectiveness.

[49] Price-based approaches to water conservation also compare favorably to CAC regulations in terms of monitoring and enforcement. In terms of predictability, neither policy instrument has an inherent advantage over the other. Likewise, neither policy instrument has a natural advantage in terms of equity. Under price-based approaches, low-income households are likely to contribute a greater share of a city's aggregate water consumption reduction than they do under certain types of nonprice demand management policies. But progressive price-based approaches to water demand management can be developed by returning some utility profits due to higher prices in the form of consumer rebates. Such rebates will not significantly dampen the effects of price increases on water demand, as long as rebates are not tied to current water consumption.

[50] Raising water prices (like the elimination of any subsidy) is politically difficult, but there may be political capital to be earned by elected officials who can demonstrate the cost-effectiveness advantages of the price-based approach, the potential to achieve greater gains in water conservation for the same cost as CAC approaches, or the ability of price-based approaches to avoid the "reduce now, pay later, anyway" problem of CAC approaches. At a minimum, communities choosing politically popular low water prices over cost effectiveness should understand this tradeoff. Where water rate setting officials are constrained by law from raising water prices, a discussion of the real costs of these constraints would be useful.

[51] In comparing price and nonprice approaches to urban water conservation, we have highlighted some important areas for future research in the economics of water conservation. These include: empirical estimation of industrial demand elasticities and industrial responses to nonprice policies (since the focus of the literature has primarily been on residential consumption); quantification by economists of the economic losses from technology standards, rationing, and other CAC approaches in specific cases, and effective communication of such results to the broader water resource management community; theoretical and empirical investigation of the implications of political and legal constraints on pricing for the relative efficiency of market-based and CAC approaches; the design of market-based water conservation approaches that are explicitly (and not just potentially) progressive; and modeling the political economy of water conservation policy instrument choice.

[52] We are reminded of the debate, beginning in the late 1980s, over market-based approaches to pollution control. While some opponents of environmental taxes and tradable permit systems still resist these approaches, policymakers have succeeded in implementing them in many cases, achieving impressive pollution reductions at great cost savings over more prescriptive approaches. A similar shift in the area of water conservation, where the principles are essentially the same, is long overdue.

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