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by

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Heterogeneous responses to water conservations programs: the case of residential users in Los Angeles

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Abstract: We propose a detailed analysis of heterogeneity in households' responses to water conservation programs (price increase, voluntary and mandatory conservation) during periods of water shortage. Using a unique dataset covering water consumption of all residential users in Los Angeles (California) during the drought (1988-1992), we show that households generally were responsive to the conservation measures but that the magnitude of households' responses varies depending on the instrument and on households' characteristics, in particular the size of their lot. Price elasticity is estimated between –0.29 and –0.47 in the high season (June-October), and between 0 and –0.19 in the low season (November-May). Results suggest that the voluntary conservation program [resp. mandatory conservation program] induced a reduction in water use which varies from 1 to 13% [resp. 21% to 29%] depending on the season and the size of the lot. The achieved reduction in consumption is however very similar across households. These data also allow us to compare the effectiveness of price and non-price policies in terms of water savings. Finally, welfare calculations suggest that households with the smallest lot sizes (and lowest income) suffered the greatest loss during the implementation of the water conservation programs.

Key words: water conservation; residential use; heterogeneity in behavior; panel data.

JEL codes: C23, D12, Q25

1. Introduction

Water is becoming a central issue in California today, especially in view of the projected rate of population growth.[1] If policies to develop alternative sources of water supply (such as groundwater banking, recycling, and desalination) are currently discussed, there is also a lot of effort devoted to the promotion of water conservation, in particular in the residential sector.[2] Among other actions, the California Urban Water Conservation Council (CUWCC), a voluntary association of water utilities founded in 1991, edited a list of 14 best management practices (BMP) including for instance residential plumbing retrofit (BMP 02), school education programs (BMP 08), and conservation pricing (BMP 11). The main purpose of these measures is to induce a permanent change in the behavior of households, by increasing users' awareness about water scarcity, and by encouraging adoption of water-saving devices. Because this behavioral change may take some time, these measures can be considered as "long-term" measures. When a utility is facing an unexpected water shortage, most of these measures are likely to be inappropriate. Alternative and more "radical" tools have to be considered such as the distribution of water-saving devices (low-flow showerheads, toilets dams, etc.), television, radio, and newspaper announcements, implementation of voluntary and/or mandatory conservation programs, or quantity restrictions limiting the amount of water the household can purchase. Such measures can be described as "short-term" measures since they are designed in order to induce an immediate change in behavior. Contrary to the "long-term" measures defined above, "short-term" measures are likely to modify households' behavior only during the period of the drought.

Among all possible water conservation programs, pricing policies have been the most extensively analyzed by economists (see Hanemann 1998, Arbués et al. 2003, or Dalhuisen et al. 2003 for comprehensive surveys). The large number of empirical studies assessing the influence of price variation on water demand (i.e. providing estimates of price elasticities) contrast with the few empirical evaluations of the effectiveness of non-price management policies (public information campaigns, subsidies to encourage adoption, use restrictions, etc.), and in particular during periods of water shortage, the so-called "short-term" measures.

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[1] The California Department of Finance (DOF) projects that the population may reach about 48 million by 2030 - an additional 12 million people.

[2] Even if municipal demand currently accounts for about four times less than agricultural demand in California, the consumption of residential users is expected to increase in the near future. In cities like Los Angeles, about two-third of total water consumption is accounted for by residential customers.

Exceptions are Martinez-Espiñeira and Nauges (2004) on European data, and Renwick and Green (2000) on data from the US. Martinez-Espiñeira and Nauges (2004) compare the effectiveness of price versus non-price water conservation measures using aggregate data from Seville (Spain) between 1991 and 1999. This time period included both normal conditions and the unusual conditions associated with the drought of 1992-95. Various conservation measures have been implemented in the city such as media campaigns, supply restrictions, temporary outdoor-use bans, and consumption control inspections. The price elasticity is found equal to -0.10 and a one-hour restriction of supply per day is found to have a similar impact on consumption as a 9% increase in price. Renwick and Green (2000)'s study covers residential demand in eight Californian water agencies[3] over the 1989-1996 period. The occurrence of droughts between 1985 and 1992 called for continued conservation and various price and non-price conservation measures were implemented in the surveyed agencies. These authors consider six basic types of policies: public information campaigns, low-flow toilet rebate programs, distribution of free plumbing retrofit kits, water rationing/allocation policies, restrictions on certain types of water use, and San Francisco Water District's compliance affidavit policy. Econometric estimation is made using agency-level data on mean monthly single family water use over the 8-year period. The model combines price equations, climate equations, and water demand equations. The latter includes socioeconomic characteristics (median household income, number of people per household, lot size) averaged over each service area. Price elasticity is estimated at -0.16 over the year, and at –0.20 for the summer months. Estimated coefficients associated to the non-price conservation measures suggest that more stringent mandatory policies were more effective in reducing water use than voluntary measures. Water rationing and use restrictions were found to induce a reduction of 19 and 29% respectively while public information campaigns and retrofit subsidies were found to reduce average household use by 8 and 9% respectively. This study provides useful insights for policy makers regarding the relative effectiveness of price versus non-price policies. Renwick and Green point out several limits of their approach. First assessing the effectiveness of various instruments across water agencies relies on the assumption that these instruments are defined the same way from one agency to another. Furthermore the use of aggregate data does not allow one to control for households' heterogeneity.

[3] San Francisco Water District, Marin Municipal Water District, Contra Costa Water Agency, East Bay Municipal Utility District, City of San Bernardino, City of Santa Barbara, Los Angeles Department of Water and Power, and City of San Diego.

The main purpose of the present paper is to add to the scarce empirical literature on effectiveness of price versus non-price policies during periods of water scarcity. A particular emphasis will be put on the analysis of heterogeneity in behavior on the one hand, and on the measurement of welfare losses implied by the implementation of these policies on the other hand. The analysis will rely on a database which covers water consumption of all households served by the Los Angeles Department of Water and Power (LADWP) over the drought period (1988-1992). Various conservation measures have been implemented by the City of Los Angeles and LADWP during the drought, among them a voluntary conservation program in 1990, a mandatory conservation program in 1991, along with constant price increases over the period. Not only the panel form of the data makes it possible to isolate an unobservable time-invariant household-specific effect, but the large sample size also allows the parameters of the water demand function to be made dependent upon households' characteristics such as the size of their lot. From these data, we are also able to compare the effectiveness of price versus non-price policies as a means of reducing demand during periods of limited supply availability. Finally, we measure the welfare loss induced by the voluntary and mandatory conservation programs. All along, consistent panel data techniques are used. Results indicate that households generally were responsive to the conservation measures but that the magnitude of households' responses varies depending on the instrument and on households' characteristics, highlighting the importance of controlling for heterogeneity.

2. Background

Los Angeles is located in an arid region, prone to periodic droughts, with little native water supply. For that reason, the city has long relied on imported water to meet the demand of its 3.8 million residents.[4] Between 1987 and 1992, California experienced one of its most severe drought in history. During that period, annual precipitation in the state was about three-quarters of its recorded historical average, while runoff was only one-half of average.[5] In Los

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[4] The city draws from several sources of water: Eastern Sierra Nevada water delivered via the Los Angeles Aqueducts, local groundwater, and purchased water from the Metropolitan Water District of Southern California via the California Aqueduct and Colorado River Aqueduct.

[5] Precipitation includes water that evaporates or is absorbed by vegetation; runoff represents water that can be captured by the state's reservoir system and used by its population.

Angeles, precipitations were below normal levels in Winter and Spring from 1988 to 1991 (see Figure 1).

Major conservation programs were put in place during the drought of 1987-1992. In 1988, the City adopted a plumbing retrofit ordinance to mandate the installation of conservation devices in all properties and require water-efficient landscaping in new construction. At the beginning of 1990 (April), Mayor Bradley called for voluntary conservation and threatened to implement mandatory conservation program if this goal was not achieved. At the same time, and in order to help households achieve the required reduction in water use, the ultra-low-flush (ULF) Toilet Rebate Program was inaugurated, followed two years later by the ULF Toilet Distribution Program. The voluntary conservation program continued until March 1, 1991 when a mandatory conservation program was introduced which required all LADWP customers to reduce their water use by at least 10% compared to their usage in the same period in 1986, or otherwise face a series of punitive fines.[6] On May 1, 1991, the conservation requirement was increased to 15%. This continued until the summer of 1992, when the mandatory conservation program was terminated. Water scarcity was also signalled through regular price increases over the period. Water price as charged by LADWP is the sum of the base charge and Total Adjustment Factors (TAF).[7] The base charge (in US dollar per 100 cubic feet, HCF[8]) varies across the year. It is generally increased between April and September, when outdoor water demand reaches its maximum. Adjustment factors[9] are calculated four times each year and take effect January 1, April 1, July 1, and October 1, respectively (see table A1 in Appendix for monthly water rates over the 1988-1992 period). The price charged for water to residential users almost doubled between January 1988 ($0.776 per HCF) and December 1992 ($1.545 per HCF).

Overall, these programs had a significant impact on daily water use as can be seen from Figure 2 (corresponding numbers, in gallons per household per day, are shown in table A2 in Appendix): daily water use decreased by 21% (on average) between 1988 and 1992.

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[6] Because our database starts in 1988 we are not able to check if each household complied or not with the 10% requirement.
[7] LADWP is not in charge of sewage so these rates do not include any sewage charge.
[8] 1 HCF corresponds to 748 gallons.
[9] TAF include 1) a water procurement adjustment which recovers purchased water, demand side management and reclaimed water expenditures; 2) a water quality improvement adjustment which recovers expenditures to upgrade water quality in order to equalize it throughout the City and expenditures for facilities approved in order to meet State and Federal Water quality standards; 3) a water revenue adjustment which credits any excess revenue or recovers any shortage in revenue due to variation in water sales.

The reduction in water use was gradually achieved, starting in April 1990, at the time when the voluntary conservation program was launched. Water use was at its lowest (over the 1988-1992 period) during the summer of 1991, when the conservation programs were the most stringent. Consumption increased again from April 1992 (even if it remained below pre-1990 levels), when the mandatory conservation program was stopped. These figures illustrate the "short-term" effect of those conservation programs imposing periodic water restrictions.

Daily water use varies a lot across the seasons (see Figure 2). Consumption increases from May to October, when precipitations come close to zero. We report in table 1 average daily water use, over the 1988-1992 period, by season, and by lot size groups (four categories).[10] Daily average varies from 326 gallons for households having the smallest lots to 758 gallons for households owning the biggest lots. The difference in water use between the high season (June to October) and the low season (November to May)[11] gives an idea of the amount of water used for landscape irrigation. From these numbers, we would estimate outdoor water use to vary from 23% of overall consumption in the first lot size group to around 30% in the last group. These estimates correspond to the ones reported in Hanemann (1998) or Hanak (2005) for the coastal zones.[12]

Since outdoor water use is generally more elastic than indoor water use (Arbués et al. 2003, Renwick and Green 2000), we would have expected the largest reductions in water use to be achieved during the high season and for households with the biggest lot sizes. Quite surprisingly, the largest reductions were achieved during the low season (between 25 and 28% of decrease), and the achieved reduction in water use was almost the same across lot size groups. This suggests that households, at the beginning, did not respond to the water conservation program by cutting their outdoor consumption; instead they may have benefited from the ULF toilet rebate program. Chesnutt et al. (1994), who tried to evaluate the outcome of the ULF toilet program, estimate the net savings per ULF toilet at 21.6 gallons per device per day. Knowing that the mean number of replaced toilets per single-family household was in the range [1.3;1.5], the estimated savings per household is in the range [28;32] gallons per

[10] Category 1: less than 7,499 sq. ft.; category 2: from 7,500 to 10,999 sq. ft.; category 3: from 11,000 to 17,499 sq. ft.; category 4: 17,500 and above.
[11] We follow LADWP definition of "low season" (November 1 through May 31) and "high season" (June 1 through October 30).
[12] If on average for the state of California, outdoor water use accounts for 41% (2000 figures) of total residential use, this proportion varies between the interior valleys (over half) and the coastal zones (less than one-third), (Hanak, 2005).

day. Average consumption varies also across temperature zones. In particular water use in the high temperature zone significantly outweighs water use in the low and medium ones. The achieved reduction in water consumption over the period was also slightly higher in the high temperature zone, in both seasons.

3. Model specification

Our purpose is to study how households' characteristics may influence households' responses to the main conservation programs, namely the variation in prices, the voluntary conservation program, and the mandatory conservation program. We do not know which household benefited from the ULF toilet rebate program. However we believe this is not an issue here as this program was untargeted (i.e. it was not targeted to specific households). It can simply be seen as a tool for residential users willing to participate in the conservation programs.

The response to the voluntary and mandatory conservation programs will be assessed from the estimation of a water demand function (that is assumed linear in the parameters) over the 1988-1992 period. From 1988 to 1992 all residential users were charged a flat rate, which simplifies the estimation of the water demand function. Water demand is commonly specified as a function of water price, climatic conditions, and household characteristics. To assess the effectiveness of the conservation measures, we create two category variables. The voluntary program variable, *VP*, takes the value of 1 for billing periods covered by the voluntary conservation program (from 1 April 1990 to March 1991), and 0 otherwise. The mandatory conservation variable, *MP*, takes the value of 1 for billing periods covered by the mandatory conservation program (from March 1991 to April 1992), and 0 otherwise.[13]

The demand function for water in billing period t for household i thus reads:

$$Q_{it} = \beta_0 + \beta_1 P_{it} + \beta_2 PREC_{it} + \beta_3 TEMP_{it} + \beta_4 VP_t + \beta_5 MP_t + Z_i \gamma + \alpha_i + \varepsilon_{it} \qquad (1)$$

[13] The mandatory program asked for a 10% reduction in water use at the beginning, followed two months after by a 15% requirement. We tried to separately identify the impact of the 10% and 15% requirements. Specification tests showed that their effects were not statistically different. For that reason, we use a unique dummy variable for the whole period covered by the mandatory program.

where P, $PREC$, $TEMP$, and Z represent average price[14], rainfall, maximum temperature, and the vector of household's characteristics respectively, the latter being time-invariant. Q is average daily water consumption of the household. The β 's and γ 's are unknown parameters to be estimated, α_i is the unobservable household specific effect, and ε_{it} is the usual idiosyncratic error term, assumed of mean 0 and constant variance. α_i , assumed time-invariant, will control for household unobserved heterogeneity.

4. The data

Data on water use and price from January 1988 to December 1992, for all residential units (around 550,000), have been provided by LADWP. Since our focus is on heterogeneity in households' behavior, we select the single-family residential customers who are individually metered and billed.[15] We only keep those households who have been billed all over the period and we exclude households for whom water consumption was not actually read on the meter but estimated. Since the remaining sample was still untractable, we randomly selected a sub-population of households. The sample we analyse in the present paper is an unbalanced panel gathering 177,834 single-family residential customers.

Each household is billed for its water consumption on average every two months, but the date of meter reading varies from one household to another. LADWP data provides information on the date of meter read and the amount of water use since last meter read. From that and knowing monthly water rates, we compute, for each household, the bi-monthly bill assuming that consumption is uniformly distributed across the billing period, and we derive the corresponding average price over the billing period.[16] The variation in billing dates from one household to the other provides a cross-sectional variation in prices, in the sample.

[14] The choice of the price variable (average versus marginal price) has been debated for a long time. We choose here the average price as we believe that households are more likely to know the total amount of their bill and their total consumption (and thus they are able to infer an average price) than to be informed about the marginal price which varies every three months.

[15] Residents of multifamily units are usually not metered and billed individually; instead there is a single bill for the entire building.

[16] For example, assume that water meter reads 60HCF on May 15, 1989 and covers consumption of the last 60 days. It is assumed that the household used 15HCF from March, 16 to March, 31, 30HCF in April, and 15HCF in first half of June. Total bill is computed as follows: $BILL = (0.670 + 0.222) \times 15 + (0.805 + 0.218) \times 30 + (0.805 + 0.218) \times 15 = 59.415$ US\$. Average price is $P = 59.415/60 = 0.990$ US\$/HCF in this particular example.

LADWP database also contains, for each billing unit, information about lot size (four categories) and temperature zones (low, medium, and high). We believe that lot size group is a relevant variable to analyse heterogeneity for two reasons: first, water use is dependent upon lot size (through the amount of water used for outdoor purposes), and second, households within the same lot size group have homogeneous characteristics: households owning bigger lot sizes are in general more educated, wealthier, and live in bigger and more expensive houses (see table 3).

We get data from the National Weather Service in Los Angeles (station of Los Angeles civic center) on maximum temperature and total precipitation for each month from January 1988 to December 1992. From those monthly observations we compute the average maximum temperature and rainfall over the billing period (weighted by the number of days in each month covered by the bill), for each residential user.

A census tract identification number in the LADWP data base allowed us to match LADWP data with 1990 Census block group data (source: US Census Bureau). A Census block is a statistical subdivision of a county and generally has between 600 and 3,000 people. Census blocks are designed to be homogeneous with respect to population characteristics, economic status, and living conditions. We gathered information on education level, median income, median value of the house, house vintage, number of rooms, and number of owned versus rented housing units. We attribute to each household the value of each characteristic corresponding to the census block he belongs to. Census data are constant over the 1988-1992 period.

5. Estimation procedure

Because outdoor water use represents a significant share of household daily consumption and because households' behavior is likely to vary depending upon the amount of water used for outdoor purposes, we propose to estimate the demand model on sub-samples likely to differ on that respect. The amount of water used for outdoor purposes will likely depend upon: the season (low versus high), the temperature zone (low, medium, high), and the size of the lot. Hence we propose to estimate the model separately for the low season and the high season, and for each temperature zone. We then allow the parameters β_1, β_4, and β_5 to vary across lot size groups, to account for heterogeneous responses to price variation, the voluntary conservation program, and the mandatory conservation program. This specification will allow us to use Wald tests in order to test for equal responses across households with different lot sizes.

The specification of an unobservable individual effect (α_i) in the model calls for the use of specific estimation techniques. Only if $\alpha_i = 0 \forall i$ will Ordinary Least Squares (OLS) provide consistent and efficient estimates. If individual effects are not equal to 0, the choice of the appropriate estimation technique depends on the correlation between the individual effect and the observable explanatory variables in the model. If $E(\alpha_i X_{it}) = 0 \forall i,t$ and $E(\alpha_i Z_i) = 0 \forall i$ where *X* gathers all time-varying variables, then Generalized Least Squares (GLS) will be the best unbiased estimator. However if one of these assumptions is violated then GLS will be inconsistent and a Within estimator will have to be preferred. The Within estimation procedure consists in applying OLS on the model in which all variables are deviated from their time means. The Within transformation not only wipes out the individual effects (α_i), source of the endogeneity problem, but also the variables in Z_i which do not vary over time. However the associated coefficients, the γ's, can be recovered from the regression of the estimated individual effects $\hat{\alpha}_i$ on Z_i (Baltagi, 2003). The Within estimator will be consistent whatever the correlation between the individual effect and the explanatory variables, but will be efficient only if $E(\alpha_i X_{it}) \neq 0$ or $E(\alpha_i Z_i) \neq 0$. The exogeneity assumption will be tested using the test described in Hausman (1978).

6. Estimation results

Six models have been estimated: Model 1 (low temperature zone, high season); Model 2 (low temperature zone, low season); Model 3 (medium temperature zone, high season); Model 4 (medium temperature zone, low season); Model 5 (high temperature zone, high season); Model 6 (high temperature zone, low season). In all six models, the dependent variable is household average daily consumption (in HCF). In addition to price and dummy variables accounting for the implementation of the voluntary program and the mandatory program, the following explanatory variables are included:[17]

Climate variables :

- total rainfall over the billing period (inches),
- maximum temperature over the billing period (°F).

Demographic variables (the census block is the unit of observation):

- the share of households with a high school level (%),
- the share of households with a college level (%),
- the share of households with a graduate level (%),
- the share of households owning his property (%),
- the median income ($1,000),
- the share of housing units built between 1980 and 1990 (%),
- the share of housing units built between 1960 and 1980 (%),
- the median value of the house ($1,000),
- the share of housing units having more than 7 rooms (%).

The best fit was obtained for models in which average daily consumption (the dependent variable), average price, median income, and median value of the house were taken in logarithms.

Specification tests performed on the six models show that the Within estimation procedure has to be preferred in all cases (see table 4). The Hausman test rejects the null of exogeneity (i.e. non-correlation between the explanatory variables of the demand model and the individual effects) in all six models. The F-test that all individual effects are zero is also rejected in all six models, comforting the choice of the Within estimation procedure instead of OLS. Finally the Wald tests (testing for the null that price increase, the voluntary program and the mandatory program have similar impact across households with different lot sizes) confirm heterogeneous responses across households. Consequently the discussion of the results that will follow will be based on estimates obtained using the Within estimation technique and allowing for heterogeneous responses across lot size groups. Estimated

[17] Different sets of explanatory variables have been tried. The model presented here was the best in terms of goodness-of-fit measures.

parameters for the six models are shown in Appendix (tables A3 to A5). In all six models, we report parameters estimated by OLS, Within estimation procedure (without any heterogeneity in the parameters), and Within estimation procedure (allowing for heterogeneity in the parameters). In the six models all coefficients generally exhibit expected signs and are statistically significant.

Table 5 describes the impact on daily water use of price increases, the voluntary and the mandatory programs, by season and by temperature zone, for each lot size category. We report average price elasticity (which corresponds to the estimated coefficient in the log-log demand model), and the influence of the voluntary and mandatory programs is measured in terms of relative change in consumption induced by each program. For example, we find that the mandatory program led to a reduction of 28.8% of water use during the high season, for households having the smallest lot sizes and living in the low temperature zone. This corresponds to $\exp(-0.340)-1$, where –0.340 is the estimated coefficient for the dummy variable "Mandatory program x lot size 1" in table A3 in the Appendix.

Price elasticity estimates vary between –0.29 and –0.47 in the high season (these figures imply that a 10% increase in price will decrease average daily water consumption by 2.9% and 4.7% respectively), and between 0 and –0.19 in the low season. These results confirm Renwick and Green's findings that water is more price responsive in the summer months. The voluntary program exhibits a lower estimated influence on demand than the mandatory program. The implementation of the voluntary program [resp. mandatory program] led to an estimated reduction in water use between 1 and 7% [resp. 27 and 29%] in the high season, and between 8 and 13% [resp. 21 and 26%] in the low season. The stronger impact of the voluntary program in the low season may be linked to the date of implementation of the program. This program was launched in April 1990. It could be that households did not react immediately to the program (i.e. during the high season, from June to October 1990) but only after a few months (during the low season, from November 1990 to March 1991). The decrease in water use during the low season may have been achieved by taking benefits of the ULF toilets rebate program. Note however that in the three temperature zones, households having the smallest lot sizes reacted the most to the VP in the low season. On the contrary, the mandatory program had a stronger influence on demand on the high season (June to October 1991). The relative change in water use during the high season is very similar across all households, whatever their lot size, around 28%. This number is close to the estimated amount of water used for outdoor purposes. This result could suggest that the implementation of the mandatory program induced the residential users in LA to cut their outdoor consumption. Note finally that estimated effects by OLS and Within (without heterogeneity in the parameters) estimation procedures can be seen as a good proxy for the average effects of the water conservation programs over the entire population. However these numbers are misleading in cases where households' responses vary significantly across lot size groups (for example when measuring the influence of the voluntary program in the high season).

From these estimates it is possible to compare the effectiveness (in terms of water conservation) of price increases versus voluntary and mandatory conservation programs. We report in table 6 the increase in price that would have been necessary to induce a reduction in water use equivalent to the reduction achieved by the voluntary and the mandatory conservation programs. For example, a 14.2% increase in price would have been necessary in order to induce households leaving in the medium temperature zone and belonging to the first lot size group to reduce their water consumption by the same amount as they reduced consumption following the implementation of the voluntary program, in the high season. We find that the decrease in water use following the implementation of the voluntary program would have been equivalent to a price increase varying from 2% (high temperature zone, lot size group 4) to 21% (low temperature zone, high season). The increase in price necessary to induce the same reduction in water use as the mandatory program varies from 58% in the high temperature zone, lot size group 4, to 102% in the low temperature zone, lot size group 2. In the low season, the necessary increase in prices varies from one group to another, with a maximum being infinity in cases where price elasticity was not found significantly different from 0.

The influence of climatic and demographic variables confirm to expectation (see tables A3 to A5). A higher maximum temperature and lower precipitations increase water use, all other things equal. The difference in magnitude of the coefficient for rainfall between the low and high season is typical from zones where outdoor water use is important. In all cases households living in highly valued and bigger houses have a larger water consumption, all other things equal. House vintage is also found to have a significant influence on water use. Compared to houses built before 1960 (taken as the reference group), houses built after (in particular after 1980) use more water. Reasons could be that houses built after 1980 were bigger on average. Income elasticity is positive in all six models except in Model 5 where it is found negative but not significant. Income elasticity lies in the range [0.06;0.26], which is again similar on average to what was estimated by Renwick and Green. There is no clear pattern of the influence of education level on water use.

7. Welfare calculations

In this section we propose to measure the impact on welfare of the voluntary and mandatory conservation programs, following Hausman (1981).[18] We proceed as follows: we derive the predicted change in water use following the implementation of both programs from the estimated coefficients associated with the dummy variables *VP* and *MP* (we consider the coefficients estimated using the Within estimation procedure, in the model with heterogeneous parameters, proven to be consistent.). Then we determine the change in price that would have induced an equivalent change in consumption. Call P_i^1 [resp. P_i^2] the price that should be set in order to induce a change in consumption by household *i* equivalent to the change induced by the voluntary [resp. mandatory] program. If P_i^0 is the price corresponding to the observed average consumption of the household over the period, then the change in welfare induced by the voluntary program (equivalently by a price increase from P_i^0 to P_i^1), as measured by the compensating variation (*CV*), reads:

$$CV_i = \left[\left(\frac{1-\hat{\gamma}_1}{1+\hat{\beta}_1} \right) \frac{1}{I^{\hat{\gamma}_1}} \left(P_i^1 \hat{Q}_i(P_i^1, I_i) - P_i^0 \hat{Q}_i(P_i^0, I_i) \right) + I_i^{1-\hat{\gamma}_1} \right]^{1/(1-\hat{\gamma}_1)} - I_i \,, \qquad (2)$$

where $\hat{\beta}_1$ and $\hat{\gamma}_1$ are the estimated coefficients of price and income respectively. *I* represents income and $\hat{Q}_i(P_i^k, I_i)$ is estimated water use when price is P_i^k, *k=0, 1*. These predictions are derived based on the estimated coefficients shown in tables A3 to A5. The same procedure is used to estimate the change in welfare following the implementation of the mandatory program, or equivalently a price increase from P_i^0 to P_i^2.

We compute the compensating variation at the average of all variables for each lot size group, for low and high season, and for each temperature zone. Results are shown in table 7.

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[18] Hausman (1981) showed that exact welfare measures can be derived from the estimation of log-log demand functions.

As expected from results shown in tables 5 and 6, the program imposing mandatory conservation induced larger welfare losses than the program imposing voluntary conservation, in all cases. In the high season, the welfare change following the implementation of the voluntary program [resp. the mandatory program] varied from $13 to $106 [resp. from $419 to $808]. Welfare losses due to the implementation of the voluntary program are larger during the low season, in the range [$0;$264]. The welfare calculations also suggest that households living in smaller lot sizes (and thus having lower incomes on average) suffered in general larger losses after the implementation of the voluntary and mandatory conservation programs, than households living in bigger lot sizes.

8. Conclusion

We proposed a detailed analysis of households' behavior during periods of water shortage. The LADWP database, which covers water use of all residential users in Los Angeles over the 1988-92 period, provides a unique opportunity to address the issue of heterogeneity in responses to various water conservation programs (here price increase, voluntary conservation program, and mandatory conservation program). Results suggest that households in general were responsive to the conservation programs but that the magnitude of their responses varies depending upon the season and the size of their lot. Overall, we confirm Renwick and Green (2000) results that water is more price responsive in the summer months and that more stringent policies (such as mandatory conservation) reduced water use more than voluntary policies. Voluntary conservation was found more effective during the low season (October-May), probably because households benefited from the ULF toilet rebate program. Mandatory conservation was found more effective during the high season (June-October) but the relative change in water use was almost the same across the population, whatever the size of the lot. Consequently, households with smaller lot sizes (and in general lower incomes) are found to be the ones who suffered the greatest losses following the implementation of the voluntary and mandatory conservation programs.

Appendices

Table A1: Monthly water rates over the 1988-1992 period (in dollar per HCF)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1988												
Base charge	0.610	0.610	0.610	0.713	0.713	0.713	0.713	0.713	0.713	0.670	0.670	0.670
TAF[a]	0.166	0.166	0.166	0.147	0.147	0.147	0.214	0.214	0.214	0.226	0.226	0.226
Total	**0.776**	**0.776**	**0.776**	**0.860**	**0.860**	**0.860**	**0.927**	**0.927**	**0.927**	**0.896**	**0.896**	**0.896**
1989												
Base charge	0.670	0.670	0.670	0.805	0.805	0.805	0.805	0.805	0.805	0.670	0.670	0.670
TAF	0.222	0.222	0.222	0.218	0.218	0.218	0.297	0.297	0.297	0.381	0.381	0.381
Total	**0.892**	**0.892**	**0.892**	**1.023**	**1.023**	**1.023**	**1.102**	**1.102**	**1.102**	**1.051**	**1.051**	**1.051**
1990												
Base charge	0.670	0.670	0.670	0.880	0.880	0.880	0.880	0.880	0.880	0.706	0.706	0.706
TAF	0.431	0.431	0.431	0.382	0.382	0.382	0.445	0.445	0.445	0.381	0.381	0.381
Total	**1.101**	**1.101**	**1.101**	**1.262**	**1.262**	**1.262**	**1.325**	**1.325**	**1.325**	**1.087**	**1.087**	**1.087**
1991												
Base charge	0.706	0.706	0.706	0.880	0.880	0.880	0.880	0.880	0.880	0.706	0.706	0.706
TAF	0.449	0.449	0.449	0.526	0.526	0.526	0.321	0.321	0.321	0.092[b]	0.092	0.092
Total	**1.155**	**1.155**	**1.155**	**1.406**	**1.406**	**1.406**	**1.201**	**1.201**	**1.201**	**0.798**	**0.798**	**0.798**
1992												
Base charge	0.706	0.706	0.706	0.930	0.930	0.930	0.930	0.930	0.930	0.740	0.740	0.740
TAF	0.321	0.321	0.321	0.527	0.527	0.527	0.793	0.793	0.793	0.805	0.805	0.805
Total	**1.027**	**1.027**	**1.027**	**1.457**	**1.457**	**1.457**	**1.723**	**1.723**	**1.723**	**1.545**	**1.545**	**1.545**

a: Total Adjustment Factors

b: Reward for conservation resulting from reduced need for purchased water.

Table A2: Average household consumption by month over the 1988-1992 period (gallons per day)

	1988	1989	1990	1991	1992
January	323	348	420	362	298
February	325	319	374	333	259
March	382	355	354	300	245
April	440	397	368	237	232
May	470	476	394	266	327
June	473	514	462	347	426
July	558	570	501	376	444
August	595	635	558	399	491
September	558	577	516	419	472
October	547	546	508	413	469
November	462	466	448	362	389
December	420	455	429	339	337

Table A3: Demand model: parameter estimates for households in the low temperature zone

	High season (June-October)			Low season (November-May)		
	Model 1			Model 2		
	OLS[(a)]	W[(b)]	W + het[(c)]	OLS	W	W + het
Constant	-2.866	-1.076	-1.084	-3.989	-2.613	-2.595
	(0.052)	(0.020)	(0.020)	(0.052)	(0.019)	(0.019)
Average price (log)	-0.316	-0.315	-	-0.130	-0.139	-
	(0.008)	(0.004)		(0.009)	(0.005)	
Average price (log) x lot size 1	-	-	-0.324	-	-	-0.166
			(0.005)			(0.007)
Average price (log) x lot size 2	-	-	-0.287	-	-	-0.095
			(0.010)			(0.012)
Average price (log) x lot size 3	-	-	-0.292	-	-	-0.144
			(0.014)			(0.013)
Average price (log) x lot size 4	-	-	-0.322	-	-	-0.063
			(0.019)			(0.016)
Voluntary program (0/1)	-0.061	-0.061	-	-0.132	-0.136	-
	(0.003)	(0.002)		(0.003)	(0.002)	
Voluntary program (0/1) x lot size 1	-	-	-0.070	-	-	-0.137
			(0.002)			(0.002)
Voluntary program (0/1) x lot size 2	-	-	-0.054	-	-	-0.143
			(0.004)			(0.004)
Voluntary program (0/1) x lot size 3	-	-	-0.028	-	-	-0.119
			(0.005)			(0.005)
Voluntary program (0/1) x lot size 4	-	-	-0.019	-	-	-0.126
			(0.007)			(0.006)
Mandatory program (0/1)	-0.325	-0.340	-	-0.239	-0.248	-
	(0.003)	(0.002)		(0.004)	(0.002)	
Mandatory program (0/1) x lot size 1	-	-	-0.340	-	-	-0.230
			(0.002)			(0.003)
Mandatory program (0/1) x lot size 2	-	-	-0.348	-	-	-0.275
			(0.004)			(0.005)
Mandatory program (0/1) x lot size 3	-	-	-0.328	-	-	-0.269
			(0.006)			(0.006)
Mandatory program (0/1) x lot size 4	-	-	-0.327	-	-	-0.266
			(0.007)			(0.007)
Maximum temperature	0.007	0.006	0.006	0.023	0.025	0.025
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Rainfall	-0.407	-0.436	-0.435	-0.042	-0.043	-0.044
	(0.009)	(0.005)	(0.005)	(0.001)	(0.001)	(0.001)
High school	-0.048	-0.051	-0.046	-0.284	-0.280	-0.282
	(0.022)	(0.019)	(0.019)	(0.024)	(0.020)	(0.020)
College	-0.099	-0.098	-0.094	0.033	0.036	0.038
	(0.022)	(0.019)	(0.019)	(0.023)	(0.020)	(0.020)
Graduate	0.039	0.041	0.029	0.023	0.014	0.014
	(0.027)	(0.024)	(0.024)	(0.029)	(0.025)	(0.025)
Owned housing units	-0.247	-0.248	-0.243	-0.359	-0.360	-0.357
	(0.009)	(0.008)	(0.007)	(0.009)	(0.008)	(0.008)
Median income (log)	0.235	0.236	0.233	0.256	0.258	0.257
	(0.008)	(0.007)	(0.007)	(0.008)	(0.007)	(0.007)
Structure built between 1980-90	0.317	0.317	0.316	0.205	0.203	0.203
	(0.011)	(0.010)	(0.010)	(0.013)	(0.011)	(0.011)
Structure built between 1960-80	0.042	0.042	0.039	0.121	0.117	0.114
	(0.006)	(0.005)	(0.005)	(0.007)	(0.006)	(0.006)
Median value of the house (log)	0.106	0.106	0.104	0.097	0.097	0.097
	(0.005)	(0.004)	(0.004)	(0.006)	(0.005)	(0.005)
7 to 9 rooms	1.101	1.102	1.088	1.016	1.011	1.005
	(0.013)	(0.011)	(0.011)	(0.014)	(0.012)	(0.012)
Number of observations	252 781	252 781	252 781	235 812	235 812	235 812

(a): Standard errors in parentheses.
(b): Within estimates, no heterogeneity allowed in parameters.
(c): Within estimates, with some heterogeneity allowed in parameters.

Table A4: Demand model: parameter estimates for households in the medium temperature zone

	High season (June-October)			Low season (November-May)		
	Model 3			Model 4		
	OLS[a]	W[b]	W + het[c]	OLS	W	W + het
Constant	-2.468	-1.238	-1.238	-3.326	-2.602	-2.603
	(0.027)	(0.014)	(0.014)	(0.019)	(0.010)	(0.010)
Average price (log)	-0.389	-0.391	-	-0.158	-0.139	-
	(0.005)	(0.003)		(0.004)	(0.003)	
Average price (log) x lot size 1	-	-	-0.394	-	-	-0.174
			(0.003)			(0.003)
Average price (log) x lot size 2	-	-	-0.385	-	-	-0.066
			(0.006)			(0.006)
Average price (log) x lot size 3	-	-	-0.383	-	-	-0.020
			(0.010)			(0.010)
Average price (log) x lot size 4	-	-	-0.388	-	-	-0.011
			(0.014)			(0.016)
Voluntary program (0/1)	-0.057	-0.054	-	-0.094	-0.096	-
	(0.002)	(0.001)		(0.002)	(0.001)	
Voluntary program (0/1) x lot size 1	-	-	-0.058	-	-	-0.092
			(0.001)			(0.001)
Voluntary program (0/1) x lot size 2	-	-	-0.053	-	-	-0.104
			(0.002)			(0.002)
Voluntary program (0/1) x lot size 3	-	-	-0.026	-	-	-0.111
			(0.004)			(0.004)
Voluntary program (0/1) x lot size 4	-	-	-0.016	-	-	-0.112
			(0.005)			(0.005)
Mandatory program (0/1)	-0.310	-0.317	-	-0.242	-0.246	-
	(0.002)	(0.001)		(0.002)	(0.001)	
Mandatory program (0/1) x lot size 1	-	-	-0.310	-	-	-0.237
			(0.001)			(0.001)
Mandatory program (0/1) x lot size 2	-	-	-0.335	-	-	-0.261
			(0.002)			(0.002)
Mandatory program (0/1) x lot size 3	-	-	-0.331	-	-	-0.278
			(0.004)			(0.004)
Mandatory program (0/1) x lot size 4	-	-	-0.332	-	-	-0.289
			(0.006)			(0.006)
Maximum temperature	0.010	0.008	0.008	0.022	0.024	0.024
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Rainfall	-0.405	-0.400	-0.399	-0.046	-0.047	-0.047
	(0.006)	(0.003)	(0.003)	(0.001)	(0.000)	(0.000)
High school	0.192	0.194	0.195	-0.094	-0.098	-0.098
	(0.008)	(0.007)	(0.007)	(0.002)	(0.006)	(0.006)
College	-0.601	-0.603	-0.603	-0.242	-0.385	-0.388
	(0.013)	(0.011)	(0.011)	(0.002)	(0.010)	(0.010)
Graduate	0.191	0.192	0.192	0.156	0.156	0.163
	(0.018)	(0.016)	(0.016)	(0.015)	(0.013)	(0.013)
Owned housing units	-0.321	-0.323	-0.322	-0.313	-0.311	-0.309
	(0.006)	(0.005)	(0.005)	(0.005)	(0.004)	(0.004)
Median income (log)	0.097	0.097	0.096	0.086	0.086	0.086
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Structure built between 1980-90	0.411	0.410	0.409	0.344	0.346	0.342
	(0.007)	(0.006)	(0.006)	(0.007)	(0.006)	(0.006)
Structure built between 1960-80	0.306	0.305	0.303	0.291	0.294	0.289
	(0.005)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Median value of the house (log)	0.119	0.119	0.119	0.111	0.110	0.110
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
7 to 9 rooms	1.243	1.245	1.240	1.146	1.144	1.131
	(0.008)	(0.007)	(0.007)	(0.007)	(0.006)	(0.006)
Number of observations	772 162	772 162	772 162	951 886	951 886	951 886

(a): Standard errors in parentheses.
(b): Within estimates, no heterogeneity allowed in parameters.
(c): Within estimates, with some heterogeneity allowed in parameters.

Table A5: Demand model: parameter estimates for households in the high temperature zone

	High season (June-October)			Low season (November-May)		
	Model 5			Model 6		
	OLS[(a)]	W[(b)]	W + het[(c)]	OLS	W	W + het
Constant	-4.353	-1.233	-1.235	-5.433	-3.097	-3.095
	(0.034)	(0.012)	(0.012)	(0.031)	(0.010)	(0.010)
Average price (log)	-0.386	-0.403	-	-0.141	-0.115	-
	(0.004)	(0.002)		(0.004)	(0.003)	
Average price (log) x lot size 1	-	-	-0.407	-	-	-0.191
			(0.004)			(0.005)
Average price (log) x lot size 2	-	-	-0.392	-	-	-0.126
			(0.004)			(0.004)
Average price (log) x lot size 3	-	-	-0.391	-	-	-0.025
			(0.006)			(0.007)
Average price (log) x lot size 4	-	-	-0.466	-	-	0.016
			(0.008)			(0.008)
Voluntary program (0/1)	-0.042	-0.041	-	-0.091	-0.096	-
	(0.002)	(0.001)		(0.002)	(0.001)	
Voluntary program (0/1) x lot size 1	-	-	-0.053	-	-	-0.091
			(0.001)			(0.002)
Voluntary program (0/1) x lot size 2	-	-	-0.048	-	-	-0.107
			(0.001)			(0.002)
Voluntary program (0/1) x lot size 3	-	-	-0.019	-	-	-0.091
			(0.002)			(0.002)
Voluntary program (0/1) x lot size 4	-	-	-0.008	-	-	-0.074
			(0.003)			(0.003)
Mandatory program (0/1)	-0.318	-0.328	-	-0.254	-0.262	-
	(0.002)	(0.001)		(0.002)	(0.001)	
Mandatory program (0/1) x lot size 1	-	-	-0.333	-	-	-0.241
			(0.002)			(0.002)
Mandatory program (0/1) x lot size 2	-	-	-0.331	-	-	-0.262
			(0.002)			(0.002)
Mandatory program (0/1) x lot size 3	-	-	-0.321	-	-	-0.295
			(0.002)			(0.003)
Mandatory program (0/1) x lot size 4	-	-	-0.314	-	-	-0.279
			(0.003)			(0.003)
Maximum temperature	0.013	0.013	0.013	0.031	0.035	0.035
	(0.000)	(0.002)	(0.000)	(0.000)	(0.000)	(0.000)
Rainfall	-0.442	-0.446	-0.446	-0.066	-0.262	-0.067
	(0.005)	(0.003)	(0.003)	(0.001)	(0.001)	(0.000)
High school	-0.555	-0.555	-0.556	-0.675	-0.669	-0.662
	(0.008)	(0.007)	(0.007)	(0.008)	(0.006)	(0.006)
College	-0.102	-0.102	-0.103	0.017	0.017	0.030
	(0.015)	(0.013)	(0.013)	(0.014)	(0.012)	(0.012)
Graduate	0.022	0.022	0.028	-0.097	-0.097	-0.094
	(0.024)	(0.020)	(0.020)	(0.024)	(0.019)	(0.019)
Owned housing units	0.113	0.113	0.111	0.009	0.004	0.005
	(0.006)	(0.005)	(0.005)	(0.006)	(0.005)	(0.005)
Median income (log)	-0.008	-0.008	-0.006	0.055	0.055	0.055
	(0.005)	(0.005)	(0.005)	(0.005)	(0.004)	(0.004)
Structure built between 1980-90	0.199	0.198	0.197	0.251	0.249	0.245
	(0.005)	(0.004)	(0.004)	(0.005)	(0.004)	(0.004)
Structure built between 1960-80	0.138	0.137	0.134	0.142	0.141	0.143
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Median value of the house (log)	0.587	0.587	0.586	0.479	0.476	0.459
	(0.005)	(0.004)	(0.004)	(0.005)	(0.004)	(0.004)
7 to 9 rooms	0.425	0.425	0.418	0.476	0.481	0.474
	(0.008)	(0.007)	(0.007)	(0.009)	(0.007)	(0.007)
Number of observations	795 912	795 912	795 912	875 449	875 449	875 449

(a): Standard errors in parentheses.
(b): Within estimates, no heterogeneity allowed in parameters.
(c): Within estimates, with some heterogeneity allowed in parameters.

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Tables

Table 1: Overall and seasonal daily consumption, across lot size groups.

	1988-1992 period		High season (June-October)		Low season (November-April)	
	Daily average (gallons)	% change between 1988 and 1992	Daily average (gallons)	% change between 1988 and 1992	Daily average (gallons)	% change between 1988 and 1992
Lot size group						
1 – 7,499 sq. ft.	326	-21.0	372	-16.4	285	-25.4
7,500 – 10,999 sq. ft.	445	-22.3	529	-16.1	371	-28.1
11,000 – 17,499 sq. ft.	654	-22.2	790	-16.2	534	-27.6
17,500 sq. ft. and above	758	-23.1	916	-16.4	637	-27.9

Table 2: Overall and seasonal daily consumption, across temperature zones.

	1988-1992 period		High season (June-October)		Low season (November-April)	
	Daily average (gallons)	% change between 1988 and 1992	Daily average (gallons)	% change between 1988 and 1992	Daily average (gallons)	% change between 1988 and 1992
Temperature zones						
Low	386	-19.6	418	-15.9	352	-23.7
Medium	366	-20.3	420	-14.8	322	-25.5
High	492	-23.1	589	-17.1	404	-28.4

Table 3: Average value of the demographics, by lot size group.

	1 – 7,499 sq. ft.	7,500 – 10,999 sq. ft.	11,000 – 17,499 sq. ft.	17,500 sq. ft. and above
Observations	98,612	47,514	20,134	11,575
High school (%)	0.74	0.81	0.89	0.88
College (%)	0.33	0.39	0.50	0.49
Graduate (%)	0.09	0.12	0.18	0.18
Owned housing units	0.56	0.68	0.79	0.79
Median income ($1,000)	3.64	3.90	4.23	4.28
House vintage (1980-90)	0.10	0.11	0.11	0.12
House vintage (1960-80)	0.23	0.36	0.48	0.43
House median value ($1,000)	5.45	5.64	5.93	5.97
More than 7 rooms (%)	0.16	0.29	0.50	0.51
Bi-monthly bill (US $)	31.71	43.78	64.62	76.90
Ratio bill / median income	0.06	0.07	0.10	0.11

Table 4: Specification tests in the models with heterogeneous parameters

	High season (June-October)		Low season (November-May)	
	Test statistic	p-value	Test statistic	p-value
Low temperature zone				
Hausman test	3222.94	0.0000	2117.18	0.0000
F-test that $\alpha_i = 0 \forall i$	27.35	0.0000	22.41	0.0000
Wald test (price)	5.08	0.0016	17.73	0.0000
Wald test (VP[(a)])	33.33	0.0000	5.61	0.0008
Wald test (MP)	4.10	0.0065	35.91	0.0000
Medium temperature zone				
Hausman test	4667.64	0.0000	3914.80	0.0000
F-test that $\alpha_i = 0 \forall i$	24.24	0.0000	23.89	0.0000
Wald test (price)	1.05	0.3703	172.61	0.0000
Wald test (VP)	38.65	0.0000	18.27	0.0000
Wald test (MP)	39.39	0.0000	72.78	0.0000
High temperature zone				
Hausman test	6748.91	0.0000	3379.12	0.0000
F-test that $\alpha_i = 0 \forall i$	23.19	0.0000	19.21	0.0000
Wald test (price)	26.17	0.0000	250.89	0.0000
Wald test (VP)	109.72	0.0000	38.28	0.0000
Wald test (MP)	14.79	0.0000	115.78	0.0000

(a): VP (Voluntary Program) and MP (Mandatory Program).

Table 5: Quantitative impact of conservation programs on daily water use

		High season (June-October)			Low season (November-May)		
Temperature zone	Lot size group	Average Price[(a)]	Voluntary Program[(b)]	Mandatory Program[(b)]	Average Price	Voluntary Program	Mandatory Program
Low	1 – 7,499 sq. ft.	-0.324	-0.067[(c)]	-0.288	-0.166	-0.128	-0.205
	7,500 – 10,999 sq. ft.	-0.287	-0.052	-0.294	-0.095	-0.133	-0.240
	11,000 – 17,499 sq. ft.	-0.292	-0.028	-0.279	-0.144	-0.112	-0.236
	17,500 sq. ft. and above	-0.322	-0.019	-0.279	-0.063	-0.118	-0.234
OLS estimates		-0.316	-0.060	-0.277	-0.130	-0.124	-0.213
Within estimates (no heterogeneity)		-0.315	-0.059	-0.288	-0.139	-0.127	-0.219
Medium	1 – 7,499 sq. ft.	-0.394	-0.056	-0.266	-0.174	-0.088	-0.211
	7,500 – 10,999 sq. ft.	-0.385	-0.052	-0.285	-0.066	-0.099	-0.229
	11,000 – 17,499 sq. ft.	-0.383	-0.026	-0.282	-0.020[(d)]	-0.105	0.243
	17,500 sq. ft. and above	-0.388	-0.016	-0.282	-0.011[(d)]	-0.106	-0.251
OLS estimates		-0.389	-0.056	-0.267	-0.158	-0.089	-0.215
Within estimates (no heterogeneity)		-0.391	-0.052	-0.272	-0.139	-0.092	-0.218
High	1 – 7,499 sq. ft.	-0.407	-0.052	-0.283	-0.191	-0.087	-0.214
	7,500 – 10,999 sq. ft.	-0.392	-0.047	-0.282	-0.126	-0.101	-0.231
	11,000 – 17,499 sq. ft.	-0.391	-0.019	-0.274	-0.025	-0.087	-0.255
	17,500 sq. ft. and above	-0.466	-0.008	-0.270	0.016[(d)]	-0.072	-0.243
OLS estimates		-0.386	-0.041	-0.272	-0.141	-0.087	-0.224
Within estimates (no heterogeneity)		-0.403	-0.041	-0.280	-0.115	-0.091	-0.231

(a): price elasticity.
(b): measures the rate of decrease in daily consumption.
(c): as an example, the model predicts that consumption decreases by 6.7% following the voluntary conservation program.
(d): not significant at the 1% level of significance.

Table 6: Increase in price (%) that would induce the same reduction in water use than VP and MP[(a)]

Temperature zone	Lot size group	High season (June-October) Voluntary Program	High season (June-October) Mandatory Program	Low season (November-May) Voluntary Program	Low season (November-May) Mandatory Program
Low	1 – 7,499 sq. ft.	20.7	88.9	77.1	123.5
	7,500 – 10,999 sq. ft.	18.1	102.4	140.0	252.6
	11,000 – 17,499 sq. ft.	9.6	95.5	77.8	163.9
	17,500 sq. ft. and above	5.9	86.6	187.3	371.4
Medium	1 – 7,499 sq. ft.	14.2	67.5	50.6	121.3
	7,500 – 10,999 sq. ft.	13.5	74.0	150.0	347.0
	11,000 – 17,499 sq. ft.	6.8	73.6	(*)	(*)
	17,500 sq. ft. and above	4.1	72.7	(*)	(*)
High	1 – 7,499 sq. ft.	12.8	69.5	45.5	112.0
	7,500 – 10,999 sq. ft.	12.0	71.9	80.2	183.3
	11,000 – 17,499 sq. ft.	4.9	70.1	348.0	1020.0
	17,500 sq. ft. and above	1.7	57.9	(*)	(*)

(a): VP (Voluntary Program) and MP (Mandatory Program).
(*): price elasticity was not significantly different from 0. Variation in price thus should be infinite.

Table 7: Impact on welfare of water conservation programs (compensating variation computed at the mean, in $1,000)

		High season (June-October)						Low season (November-May)					
		Voluntary program			Mandatory program			Voluntary program			Mandatory program		
Temperature zone	Lot size group	OLS	W	W+het	OLS	W	W+het	OLS	W	W+het	OLS	W	W+het
Low	1 – 7,499 sq. ft.	0.095	0.095	0.106	0.685	0.734	0.701	0.308	0.306	0.264	0.861	0.843	0.581
	7,500 – 10,999 sq. ft.	0.084	0.083	0.076	0.600	0.642	0.737	0.226	0.235	0.262	0.632	0.645	1.142
	11,000 – 17,499 sq. ft.	0.081	0.080	0.036	0.579	0.618	0.625	0.113	0.126	0.105	0.316	0.347	0.402
	17,500 sq. ft. and above	0.061	0.060	0.019	0.436	0.465	0.445	0.029	0.036	0.001	0.082	0.100	0.014
	Overall	0.091	0.090	0.091	0.650	0.696	0.688	0.250	0.253	0.226	0.700	0.695	0.619
Medium	1 – 7,499 sq. ft.	0.076	0.071	0.076	0.506	0.517	0.498	0.152	0.167	0.139	0.621	0.739	0.531
	7,500 – 10,999 sq. ft.	0.066	0.062	0.061	0.438	0.449	0.486	0.082	0.080	0.040	0.335	0.352	0.455
	11,000 – 17,499 sq. ft.	0.061	0.057	0.028	0.408	0.419	0.451	0.037	0.031	0.000	0.151	0.135	0.000
	17,500 sq. ft. and above	0.057	0.053	0.016	0.379	0.390	0.419	0.017	0.013	0.000	0.071	0.055	0.000
	Overall	0.073	0.068	0.068	0.483	0.493	0.490	0.127	0.137	0.107	0.519	0.606	0.468
High	1 – 7,499 sq. ft.	0.080	0.075	0.096	0.756	0.743	0.741	0.226	0.283	0.176	1.128	1.708	0.662
	7,500 – 10,999 sq. ft.	0.079	0.076	0.090	0.751	0.746	0.780	0.165	0.184	0.206	0.822	1.109	0.966
	11,000 – 17,499 sq. ft.	0.083	0.081	0.038	0.790	0.796	0.808	0.101	0.092	0.001	0.504	0.554	1.489
	17,500 sq. ft. and above	0.066	0.065	0.013	0.628	0.643	0.559	0.049	0.036	0.000	0.243	0.220	0.000
	Overall	0.079	0.075	0.076	0.749	0.745	0.751	0.163	0.187	0.155	0.811	1.126	0.948

Figures

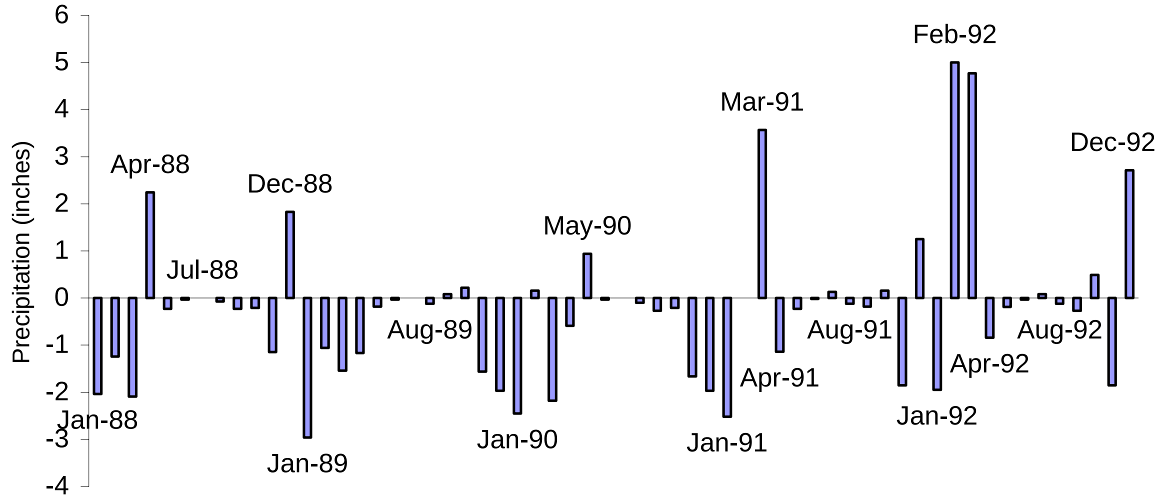

Figure 1: Departure from normal precipitations (January 1988 – December 1992)
(source: National Oceanic and Atmospheric Administration)

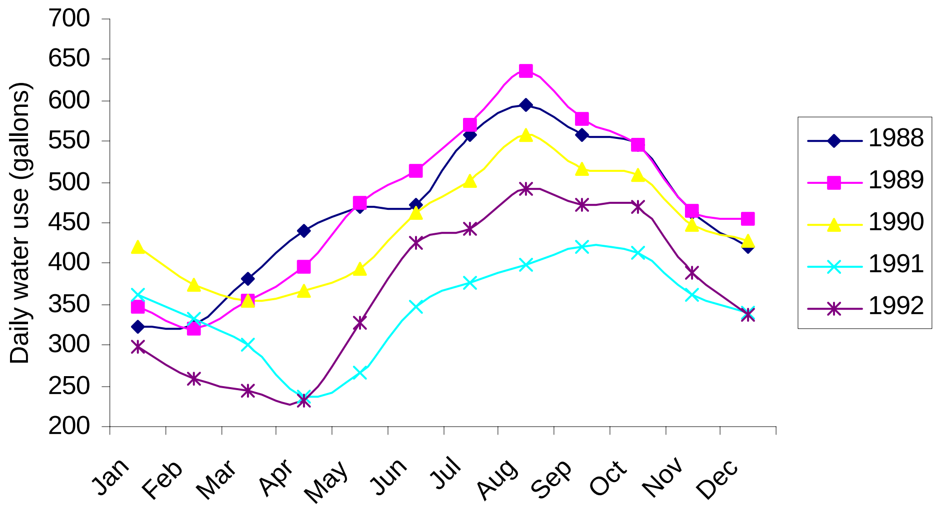

Figure 2: Average daily water use (January 1988 – December 1992)
(source: LADWP)