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Does anybody give a dam?

The importance of public awareness for urban water conservation during drought

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Abstract: Demand management has been of interest in dry climates such as Australia, Spain and the Western United States for decades. It is particularly important to understand policy options during drought conditions, as drought periods have a disproportionate effect on supply infrastructure decisions. While water-conservation campaigns aimed at inducing voluntary consumption reductions are almost universally employed by water managers in times of supply constraint, voluntary measures are generally dismissed in the economics literature as ineffective. We argue that the robust positive correlation between dam levels and consumption after controlling for policy changes suggests that there is a significant component of voluntary conservation. Furthermore, omitting dam levels from regressions may bias estimated impacts of policy changes.

Keywords: water use, demand management, pricing, behavioral aspects

1. Introduction

Fresh water is a scarce and increasingly costly resource, particularly in drier continents. Thus, the question of how to best allocate fresh water resources is becoming ever more important. According to the economics literature, the answer to this question is obvious: use markets and efficient pricing. Unfortunately for the authors of this literature, water managers seem reluctant to agree, particularly on the question of allocation during drought.

In times of relative water scarcity (i.e. drought), urban water managers typically employ a combination of price increases, mandatory restrictions (usually on outdoor uses), and campaigns aimed at inducing voluntary conservation measures - including awareness raising. Reflecting the predilection of economists, the impacts of prices on water demand have been extensively studied.[1] Mandatory restrictions have also received ample attention, generally with the conclusion that they are effective but inefficient tools for demand management. In contrast, campaigns to stimulate voluntary conservation have been the subject of relatively few econometric studies, and most authors conclude they are ineffective approaches to demand management.[2]

The contrast between the almost universal use by water managers of information campaigns aimed at eliciting voluntary conservation, and the lack of econometric evidence that they are successful, suggests two possibilities: either water managers are misguided, or the econometric studies are missing something. Citing a large body of survey literature

[1] Dalhuisen et al. (2003) provide a meta-analysis of 296 different price elasticity estimates for urban water demand.

[2] See Syme et al., 2000 for a survey of the small literature to that date. More recent contributions are discussed in section 2.

which suggests substantial impacts of voluntary conservation campaigns (of the order of 25%), Syme et al. (2000) argue in favour of the latter conclusion.

The current paper takes a novel approach to identifying voluntary demand restraint. We estimate the demand response to changing water storage (i.e. dam) levels, controlling for all observable policy changes. Informing consumers of the storage levels was central to the education campaign undertaken by the utility provider in our case study of the Australian Capital Territory. Thus, while we are not estimating the impact of the information campaign per se, we certainly expect that is contributed to the response we observe.

Including water storage levels in demand specifications also has important implications for the assessment of the efficacy and efficiency of other demand management tools. The introduction of demand management policies is endogenous, and almost invariably driven by low water levels in storage reservoirs. Thus, if there is a non-negligible voluntary response to dam levels, then omitting them from a demand specification will bias estimates of the efficacy and efficiency of other policy changes. For example, omitting voluntary response to dam level may lead to an over-estimate of the demand response to mandatory outdoor use restrictions. This, in turn, will lead to an overestimate of the welfare costs of mandatory restrictions.[3]

The relative lack of attention paid by the economics literature to the impact of voluntary water conservation measures in urban areas is likely due to a combination of the difficulty of quantifying relevant policies (Michelsen, McGuckin, and Stumpf, 1999; Syme et al., 2000; Halich & Stephenson, 2009), and the skepticism that neoclassical economics imbues for the

[3] See Ward & Grafton (2009) for a recent example of estimation of the welfare costs of mandatory restrictions compared to using price to achieve equivalent demand reductions.

likelihood of their success. Water in storages is a perfect example of common pool resource and – as classically espoused by Hardin (1968) – the neoclassical result is that no single resource user has incentive to conserve the resource since what she leaves will simply be consumed by her greedy competitors.

Since Hardin's dismal prediction, a substantial body of field and laboratory evidence has been amassed which indicates voluntary contribution of to public goods is common (Ostrom et al., 1999). The extent of co-operative versus free-rider behavior is, however, known to be highly context specific. This leaves us with an open empirical question.

The next section surveys the existing empirical literature on the effect of information campaigns for water demand management. Section 3 introduces our case study and data and section 4 explains our empirical approach. Section 5 presents results and section 6 concludes.

2. Information Campaigns, Storage Levels, and Water Conservation

The current paper contributes to the literature on voluntary conservation measures by residential consumers can make to demand management, particularly in times of drought. Water managers have used a wide variety of tools to encourage voluntary conservation, including subsidies (often in the form of rebates) for adoption of water efficient technologies, changing billing frequency and presentation of consumption information therein, home audits, campaigns to educate consumers on ways to conserve water, and information or awareness raising campaigns emphasizing the need to conserve water. Usually a number of these approaches are combined, which complicates attempts to identify the effect of individual components on demand. The intensity of a campaign is also often difficult to quantify (Michelsen, McGuckin, and Stumpf, 1999; Syme et al., 2000; Halich & Stephenson, 2009). As a result, most econometric studies simply include dummy or categorical variables to indicate the presence of a voluntary campaign of some sort (Halich & Stephenson, 2009).

The focus of our empirical analysis is on dam storage levels and – to a lesser extent – aggregate water consumption targets. Both targets and storage levels had been widely publicized in our case study period, appearing weekly in television and print news for at least two years prior to the start of our sample.[4] Thus our paper differs from other studies in that it focuses primarily on changes in the information consumers receive, rather than changes in the intensity of the information campaign.

There are several mechanisms through which we expect dam storage level to affect the conservation behavior of informed consumers. Storage levels are a direct measure of the severity of the water shortage and therefore the potential costs of maintaining current levels of consumption.[5] Thus lower storage levels may make consumers more likely to adopt purely voluntary conservation measures, adhere to mandatory (but not easily enforceable) outdoor use restrictions,[6] or report restriction violators to authorities.

There are two relevant (but small) literatures on voluntary water conservation. Firstly, a few papers examine factors such as reported attitudes, beliefs and intention to make behavioral changes to conserve water. Kantola, Syme and Nesdale (1983) found that participants who

[4] In the latter half of our sample the information campaign was intensified and electronic signs displaying daily dam level, target consumption and actual consumption were placed on five major roads. We control for this in our regressions.
[5] Consumers may view dam levels as an indicator of how soon water capture and storage expansion projects will be undertaken, with their implied financial and environmental costs. They may also view low dam levels as indicating the probability that the water may actually "run out", requiring the costly import of water.
[6] Outdoor use restrictions of varying severity were in place throughout our sample period. We include them in our empirical analysis.

watched films about Perth (their city's) water supply situation reported significantly higher intentions to conserve water compared to a control group, and that feelings of citizens duty to conserve water and concern about the water situation are closely related to behavioral intentions. Aitken et al. (1994) combined survey and informational treatment with actual water consumption observations for a sample of Melbourne households. They found that while attitudes, habits and values were very poor predictors of consumption, feedback on consumption levels relative to an appropriate mean significantly reduced consumption in the sample period.

Of particular relevance to the current paper, Yardley (2009) surveys water users from our case study area and time about their awareness of and response to the conservation information campaign undertaken by the water utility. He finds that 77% of survey respondents claimed to have changed their water use habits as a result electronic roadside signs advertizing the dam level, targets and total usage. Surveys by the water utility itself found that in 2005 98% of participants said they were aware of the current conservation campaign and, of these, 77% said the campaign had at least some impact on their consumption behaviours. A later survey by the utility found 66% of respondents said they had introduced new water saving actions as a result of the latest information campaign (Results from ActewAGL surveys, reported in Yardley, 2009).

The generally positive results suggested by survey responses contrasts with the literature which uses utility water consumption data to evaluate the effectiveness of information campaigns to promote voluntary household water conservation. Syme et al. (2000) survey this literature (to that date) and conclude that (p.551):

> Regression-based techniques seem to indicate that campaigns have little

> success. However, these types of studies, no matter how statistically sophisticated, seem fraught with problems of multicollinearity and interpretation, possibly because of unmeasured exogenous variables. For instance, campaigns may markedly affect motivation to respond to pricing schedule changes but may explain little variation in water use in regression modeling. Problems are also often encountered in satisfactorily creating a precise variable for publicity for inclusion in the analysis.

Other more recent studies not discussed by Syme et al. (2000) are unlikely to have changed their conclusion. They mostly suffer from the same shortcomings and, at best, find reductions of the order of 5-10% of mean consumption.[7] A notable exception is the paper by Halich & Stephenson (2009) which examines the interactions between mandatory restrictions, enforcement level and accompanying information campaign. Consistent with the conjecture of Syme et al., they find that while information campaigns alone achieved at most 7% demand reductions, they could significant increase the effectiveness of mandatory campaigns (contributing over 10% to average demand declines).

The current paper is similar to Halich & Stephenson in not focusing only on the direct impact of information campaigns. Our goal is to gain an idea of the economic significance of voluntary action through observing the response to changing need for voluntary action (as indicated by dam levels). We agree that heightened awareness of the need to reduce demand is likely to substantially work through increasing the effectiveness of other demand management policies (i.e. increasing response to price increases as suggested by Syme et al., or adherence to mandatory restrictions as found by Halich & Stephenson). Our study also suffers less from the colinearity identified by Syme et al. Firstly we have more identifying variation through the use of daily rather than monthly or quarterly data, and secondly because dam levels vary in considerably more complex ways than policy variables.

[7] Studies since Syme et al.'s review that we are aware of are Renwick & Green (2000), Taylor et al. (2004), Kenney et al. (2004), Coleman (2009), and Halich & Stephenson (2009).

3. Case Study and Data

We use daily water usage data[8] from the Australian National Capital region[9] from December 2005 to March 2010. The data was provided by ActewAGL[10] which also provided daily dam level measurement, water usage targets, water restriction level and water price data. The use of daily data has two advantages compared to the monthly data used in previous studies of non-price demand management measures. Firstly, it significantly reduces the extent of colinearity of the multiple policy changes that were made, an issue which has plagued most studies (Syme et al. 2000). Secondly it allows for the inclusion of detailed weather controls. For a typical Australian household sample it will be very important to control for local weather conditions which will explain a large part of the consumption variation in overall water usage.[11] Outside water usage plays a big role detached and semi-detached dwellings which use on average 130% more water than flats (Troy 2004). In the

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[8] There are typically two other types of water consumption data available: monthly postcode or suburb data and quarterly household level data. There is a tradeoff between disaggregation and frequency in the choice of usage data. This is due to the nature of the data collection where meters are commonly read off every 3 months for an individual household. In this tradeoff we chose the higher aggregation to get the highest frequency data. Although we would like to be able to control for - or interact variables of interest with - household or suburb level characteristics we find that it is foremost important to control for weather as detailed as possible. Choosing more disaggregated and still controlling for weather in a detailed way would use too many degrees of freedom and not be feasible with the existing short data sets.

[9] This in mainly Canberra and its suburbs but includes Queanbeyan just over the state boarder in New South Wales.

[10] ActewAGL is a utility joint venture formed in 2000 by the private Australian Gas Light Company (AGL) and the government owned water and electricity company (Actew). ActewAGL is the sole provider of freshwater and wastewater services in the ACT region. (for more details and history see http://www.actew.com.au or http://www.actewagl.com.au)

[11] We use a large number of weather variables in our final specification. All of these are highly significant and together explain 41% of the water usage variation in the data.

Australian Capital Territory over 90% of households live in detached and semi-detached dwellings[12] within these outdoor water use accounts for 43% of their water consumption.[13]

The weather data is from the Bureau of Meteorology's Canberra airport weather station.[14] The observations include daily weather variables such as sun-hours, precipitation, temperature, evaporation and many more.[15] We also obtained quarterly estimates of population for the region from the Australian Bureau of Statistics.[16]

All collected variables are combined to a daily time series of 1554 observations. In Figure 1 we plot the data series over the observation period. The red line shows the evolution of the dam levels from the start of our series with 68% to its low point of 30% in 2007 and its following slow non monotonic recovery through the end of our data. The blue line plots daily water usage. It shows the yearly water usage fluctuation over the seasons and we can see the stark decrease from the high 2006/2007 consumption levels in the following years. The yellow line in Figure 1 shows the introduction of water restriction levels. We observe five restriction levels in our sample. Stage 1 which we observe from the start of our sample incorporates relatively minor water restrictions. The stricter stage 2 was only briefly in place before stage 3 got introduced at the beginning of 2007. Stage 3 restrictions are very tough and forbid the use of sprinklers, watering lawns and topping up pools, and only allow watering plants with a trigger nozzle hose at restricted times. Stage 3 lasted to the end of

[12] In the ACT 81.5% are separate houses, 10.7% semi-detached dwellings and 7.6% flats (see ABS's Australian Social Trends - Housing Table 2.8 available at: http://www.abs.gov.au/ausstats/abs@.nsf/mf/4102.0)

[13] See ACT Goverment (2004, Vol. 1 page 22).

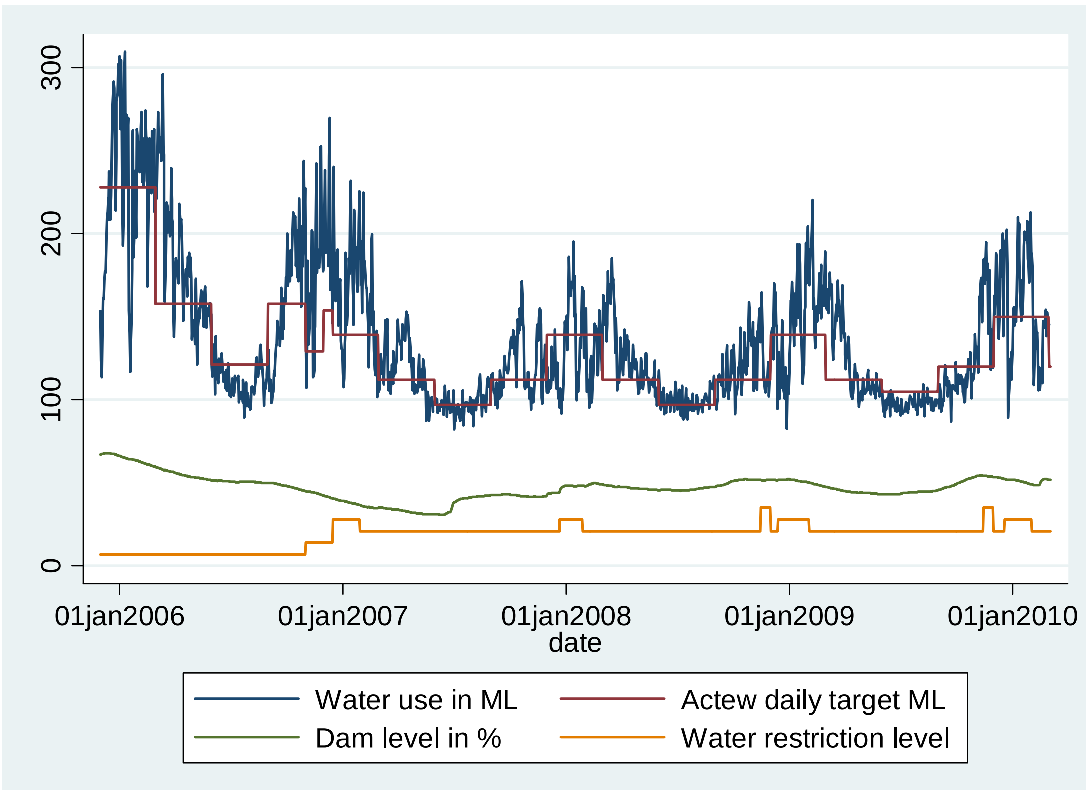
[14] This is the main weather station in Canberra with the most detailed and uninterrupted weather data from the region since 1939. It was relocated within the airport proximity in December 2010.

[15] The weather station records a total of 57 daily measures and statistics. In addition to the above there are other such as cloud cover, wind speed, humidity and air pressure for a complete list see: http://reg.bom.gov.au/climate/dwo/IDCJDW2801.latest.shtml

[16] From the ABS's Australian Demographic Statistics publication. The estimates are based on the ABS's last 2006 Census and can be found here: http://www.abs.gov.au/ausstats/abs@.nsf/mf/3101.0

our sample and is only interrupted by short summer and spring clean exemption periods. A detailed explanation of the water restriction categories can be found in the Appendix.

Figure 1. Water usage, dam level, usage targets and water restrictions



Summary statistics of our data by year are provided in Table 1. The average usage dropped by 28% to 120 mega liters a day from 2005/2006 to 2007 and has stayed constant at this lower level since. With higher rainfall in 2007 of 570 milliliter and reduced water usage the dam levels started recovering and have stayed at a similar level even with lover rainfalls of 440 milliliters in 2009.[17] Marginal water prices for the average household consuming 232

[17] The long term average rainfall in Canberra over the past 70 years was 617mm.

kiloliters a year[18] have more than doubled over the observation period from under two dollars to almost four Australian dollars. In 2010 dollars terms prices increased by 150% from $1.56 per kiloliter at the start of our observation period to $3.9 per kiloliter in 2010.

Table 1. Summary statistics

		2006	2007	2008	2009
Usage (ML)	mean	169	121	120	126
	min	89.5	82.1	88.1	87.1
	max	309.4	231.9	195.3	220.4
Dam level (%)	mean	51.8	38.2	48.3	47
	min	39.1	30.8	45.3	43
	max	66.1	48.2	52.1	54
Total rain (mm)		361.2	568.4	534.8	440
Total rain days		71	109	90	101
Marginal Cost in $/KL		1.75	2.19	3.06	3.83

With the large number of observations we can control for a large battery of contemporaneous and lagged weather variables, including moving averages, in addition to daily and monthly specific effects. Thus overcoming possible omitted variable bias and identifying the coefficients on the variables of interest more precisely.

One of the key objectives of this paper is to identify the impacts of different types of policy instruments. For that we need to understand to what extent policy responses are confounded, and what may be driving them. In particular we argue that it is essential to include the widely publicized dam levels in a regression. Figure 2 plots the policy variables price, water restriction, information campaign, and target consumption along with dam level. From the graph we can see the importance of dam level as a policy driver. The dam

[18] Troy (2004) produced statistics for average annual household consumption by type of dwelling. With separate houses using 319 kiloliters (KL), semi-detached dwellings using 193 KL and flats 138 KL.

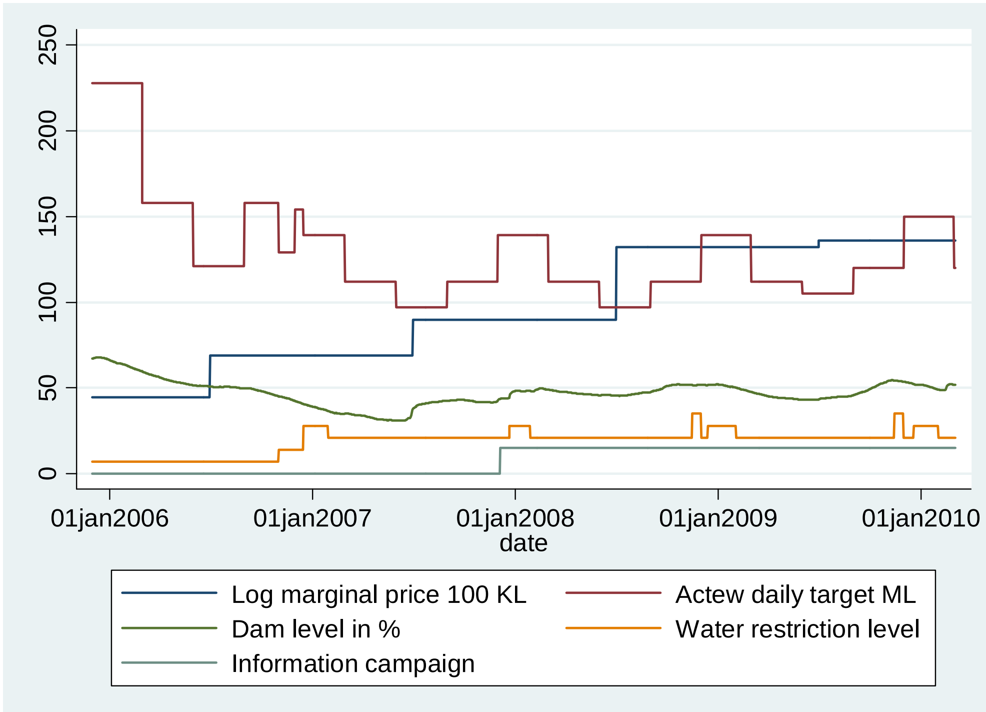
levels reached a critical record low at the end of 2006.[19] Tougher water restrictions were put in place in November 2006 and ramped up in January of 2007. The daily water targets were lowered from 228 mega liters a day the summer before to 139 a day. After the dams didn't recover much over the winter of 2007 ActewAGL also ramped up its information campaign[20] as part of which they put LED road signs on all five major Canberra traffic arteries informing about the currently measured dam level, yesterdays usage and the target usage. These measures were reactions to the dwindling dam levels in the ACT. It highlights the importance of including dam levels in our regression when people's usage behavior is driven by the indirect impacts of low storage levels through changed regulation and policies as well as by the direct communication of these levels. Under such consideration excluding dam levels from the regression would lead to bias coefficient estimates on other policy measures which themselves are driven by water storage levels.

What Figure 2 also shows is that policy levers were not moved simultaneously. In particularly, price changes were not coincident with restriction changes. This will allow us some confidence in separately identifying the impacts of the different policy types.

[19] Mr Sullivan, the Managing Direct of ACTEW, talked about the 2006 dam levels as "dangerously low". http://www.canberratimes.com.au/news/local/news/general/climate-blamed-for-high-water-use/1815827.aspx There was a seriously debate at the time to use as a last resort recycled waste water as drinking water. http://www.abc.net.au/water/stories/s1922096.htm

[20] Actew's information campaign also includes television advertisement, specific publications, mail drops, advertising on posters and in newspapers such as in The Canberra Times.

Figure 2. Usage targets, prices, dam level, water restrictions and information campaign



4. Empirical Methodology

We first check our water usage and dam level data series for their time series properties. An augmented Dickey–Fuller test rejects the null, confirming the stationary of these series. The Durbin-Watson test statistic is 1 indicating the existence of series correlation in the residuals. As a robust test for autocorrelation we use a Breusch–Godfrey test and strongly reject the null hypotheses of no serial correlation for first and higher orders. We also test for heteroskedasticity using the White 's general test and Breusch–Pagan test. Both tests strongly reject the null hypothesis of homoscedasticity.

Given the above test results we employ the Newey-West estimation of our covariance matrix to deal with the serial correlation and the heterogeneity in the data and to get heteroskedasticity and autocorrelation consistent (HAC) standard errors. Following a common practice as a simple rule suggested by Greene (2002, p. 267) Newey-West is implemented with a bandwidth of B = $(N)^{1/4}$ rounded up to the next integer. The bandwidth in our case with N = 1548 is B = 7.

The main model in the paper has the following form:

where $\ln(y_t)$ is the log of water usage in mega liters at time t. α_0 is the coefficient on a constant term. *Damlevel*$_{t-1}$ is the decimal percentile to which yesterdays combined storage reservoirs are filled with water. As argued above, dam levels have an indirect effect through demand management policies but directly affect voluntary efforts as they conveying the urgency of water conservation to the consumer. α_1 is capturing the dam levels direct effect on consumption as the main parameter of interest. Z_t represents a vector of water demand management policies. It include the log marginal price of a kilo liter of water in 2009 AU$ for the average user and low-end users at time *t*. To capture the effect of prices of both types of consumers. The ActewAGL daily water usage targets in mega liters at time *t* and we talk in more detail below what these capture. It also includes a dummy variable which equals one when the ActewAGL information campaign introduced roadside LED signs. Lastly Z_t includes a dummy variable for each restriction level equal to 1 if the respective outdoor water use restriction is in place. Stage 3 restrictions are the excluded restriction level in the regressions. The coefficients on the other restriction levels present their relative effect on consumption compared to stage 3. X_t includes all other control variables. These include an extensive set of variables from the Bureau of Meteorology to control for as much of the variation in consumption due to changes in weather. Weather controls included are rainfall and 5 days of lagged rainfall as well as a 20 day moving rainfall average. Further sun hours, evaporation and 3 days of lagged evaporation as well as a moving average of 20 days, the max temp and yesterday's maximums temperature. As discussed above these extensive set of weather controls account for the importance of outdoor water usage in our sample and in the context of outdoor water restrictions. X_t also includes dummies for weekdays which control for variations of water use on different days of the week. This is important to account for as we find significant variation across days. Generally people use less water during the week relative to the weekend. Average water use is highest on Sundays and lowest on Fridays. Finally X_t also includes month dummies to control for seasonal variations in water usage not captured by the weather controls. ε_t is a normally distributed error term with possible serial correlation and heterogeneity.

We set out to access the effects of all demand management tools and in particular the effect of dam level on consumption. To above regression framework is well suited to determine effects of prices, water restrictions, road signs or the dam level. But with targets the story of what we capture in the above regression is more complicated. Target levels change along the seasons depending on the restriction scheme in place. In this context the targets will represent a proxy for the overall policy regime as it changes in stringency across years. Controlling for seasonality what the coefficient on target levels captures is the policy tightness in form of a consumption target of the overall measures ActewAGL has currently implemented.

But what if want to learn about the direct effects of targets. Do people react to the differing target levels? Although it is an aggregate water use target for the daily consumption of the region which may be hard to asses for an individual household people see lower and higher targets being advertised. Particularly the change to a new target level at the start of a new season are communicated widely in the press and on the roadside signs.

To have a direct look if the announced target changes have any effect on water consumption we can conduct an event study. These are well known from the finance literature.[21] Looking at a narrow time period around the announced target changes all other effect from policy change or seasonal weather effect can be assumed to not change. Any unexplained variation in consumption that changes systematically before and after the target change can then be contributed to people reaction to the announced target levels.

In classical example from the finance literature the event is an announcement. The announcement can be of positive or negative nature about a listed stock. The event study methodology compares the abnormal return of the stock the days before the announcement to the days after the announcement.

In our case the change in target level is the news or the event. We will look at the unexplained variation in water consumption controlling for weather data and any other changing variables. We can then look at the difference in `abnormal' water consumption - the error term of our regression - in the weeks before and after the announcement.

We look at the differences graphically and run tests to see if the average `abnormal' water consumption is different before and after the target change. We perform individual t-test for each event window to see if the difference is significant. We also run a combined test over all events to look at the cumulative `abnormal' water consumption across all target changes. The event study graph in Figures 3 will give an intuitive view of the methodology described above. For more details see also Laplante, Dasgupta and Mamingi (1998). In the

[21] MacKinlay (1997) gives a very good overview.

next section we will first present our main regression results and robustness checks before we turn to the event study results later on.

5. Results

The main results of the paper are presented in Table 2. The first column in table 2 represents the correlation of (lagged) dam level with consumption, controlling for all weather and other exogenous controls, but no policy variables. The coefficient of 0.011 suggests that the combined policy-induced and voluntary response to a 10% decrease in dam level would result in a demand decrease of around 11%. Moving across the columns we progressively add policy controls. As we expect the coefficient on dam level decreases, but even with a comprehensive set of policy controls remains statistically and economically significant. We interpret the coefficient in column 5 as indicating that a 10% decrease in dam level will induce voluntary conservation reductions of 4.5%.

Table 2. Main Regression Results

	(1) Per capita use (ln)	(2) Per capita use (ln)	(3) Per capita use (ln)	(4) Per capita use (ln)	(5) Per capita use (ln)
Dam level in %	0.0114***	0.00692***	0.00553***	0.00646***	0.00451***
	(8.85)	(8.42)	(4.45)	(4.00)	(2.80)
Marginal cost (ln)		-0.274***	-0.200***	-0.162***	-0.150***
		(-18.80)	(-5.72)	(-3.99)	(-3.80)
Marginal cost low users(ln)		-0.346***	-0.272***	-0.250***	-0.191***
		(-11.02)	(-5.32)	(-4.83)	(-3.69)
Stage 1 restrictions			0.0710*	0.0664	-0.0194
			(1.73)	(1.54)	(-0.47)
Stage 2 restrictions			0.114***	0.120***	0.0923***
			(4.60)	(4.81)	(3.42)
Summer exemption			-0.0383	-0.0359	-0.0122
			(-1.52)	(-1.42)	(-0.48)
Spring clean			-0.0367	-0.0317	-0.0207
			(-1.20)	(-1.06)	(-0.75)
Roadside signs				-0.0301	-0.0217
				(-1.33)	(-1.01)
Water use target (ln)					0.404***

					(4.13)
Observations	1539	1539	1539	1539	1539
Adjusted R^2	0.770	0.882	0.886	0.887	0.890

Notes: *t* statistics in parentheses: $^{*}p<0.1$, $^{**}p<0.05$, $^{***}p<0.01$. Standard errors are heteroskedasticity and autocorrelation consistent (Newey-West). (ln) indicates a variable that enters in logarithmic specification. ML stands from mega litres. Each regression contains month and day of the week dummies and the complete set of weather controls described in Section 4.

The coefficients on price also decrease as expected when we control for additional policy variables, though the estimates in all columns lie comfortably within the range reported in the literature. Dalhuisen et al. (2003) find a mean of -.41 and a median of -.35 in a meta-sample of 314 price elasticities from 64 studies. Our preferred specification for price is column 3 since signs are insignificant and targets are close to collinear with price changes once month dummies are included. In this specification the elasticity estimate for the low-user and average-user marginal costs are around -.27 and -.20 respectively. To compare these figures to the literature (which generally has disaggregated data and therefore a single relevant marginal costs) we need to add the coefficients together.[22] Thus our equivalent total price elasticity estimate is -.47. This lies between recently estimated Australian short-run marginal price elasticities of -.35 by Grafton & Kompas (2007) for Sydney and the -.51 estimated by Hoffmann et al. (2006) for Brisbane.

The estimated effect of increasingly strict mandatory restrictions on outdoor uses was relatively small at a maximum of 12%. It is difficult to place these relative to the literature since a dummy variable is generally included for “any restriction” (Kenney et al., 2004; Renwick & Green, 2000; Grafton & Ward, 2010). However, according Ward (pers. comms.), Grafton & Ward (2010) found no significant difference on consumption when they controlled for individual levels of restriction.

[22] The intuition of adding the two elasticity estimates can be obtained from the thought experiment of calculating the effect of an uniform price increase which increased both marginal costs by, say, 10%.

In columns 4 and 5 we find a small negative effect of the introduction of roadside dam and target information signs, much as we would expect. The effect is, however, statistically insignificant. Finally in column 5, the coefficient on the consumption target is highly economically and statistically significant. This is no surprise as the target is set jointly by state government and the water utility and therefore acts as a proxy for the level of demand management effort exerted by both organizations. Target captures other aspects of policy not captured by the variables in the first 4 columns, notably policies aimed at non-residential users.

Table 3 shows the robustness of the coefficients from our preferred specification – column 3 of Table 2. Firstly in column 2 we drop the dam level from the regression and see that a number of our estimates change substantially. In particular the price elasticity on the marginal cost for the average consumer almost halves, leaving it less than half the elasticity estimated for the marginal cost faced by the low-end users. Meanwhile the impact of stage 1 restrictions (compared to stage 3) becomes large and significant and the summer exemption becomes significant with the wrong sign.

Table 3. Robustness Checks

	(1) Per capita use (ln)	(2) Per capita use (ln)	(3) Per capita use (ln)	(4) Per capita use (ln)	(5) Per capita use (ln)
Dam level in %	0.00553***		0.00536***	0.00255***	0.00513***
	(4.45)		(4.27)	(3.91)	(2.80)
Marginal cost (ln)	-0.200***	-0.112***	-0.282***	-0.0899***	-0.176***
	(-5.72)	(-3.88)	(-4.50)	(-4.92)	(-3.05)
Marginal cost low users(ln)	-0.272*** (-5.32)	-0.252*** (-4.86)	-0.296*** (-5.61)	-0.128*** (-4.76)	-0.217*** (-2.65)
Stage 1 restrictions	0.0710*	0.179***	0.0723*	0.0323	
	(1.73)	(6.14)	(1.77)	(1.54)	
Stage 2 restrictions	0.114***	0.119***	0.116***	0.0494***	
	(4.60)	(4.68)	(4.73)	(2.73)	
Summer exemption	-0.0383	-0.0660**	-0.0387	-0.0212	-0.0355
	(-1.52)	(-2.57)	(-1.53)	(-1.33)	(-1.18)
Spring clean	-0.0367	-0.0265	-0.0380	-0.0225	-0.0320

	(-1.20)	(-0.84)	(-1.34)	(-1.07)	(-0.94)
Time trend			0.0000626		
			(1.50)		
Lagged dependent variable				0.545***	
				(20.16)	
Observations	1539	1539	1539	1539	1163
Adjusted R^2	0.886	0.881	0.887	0.917	0.825

Notes: t statistics in parentheses: $^{*}p<0.1$, $^{**}p<0.05$, $^{***}p<0.01$. Standard errors are heteroskedasticity and autocorrelation consistent (Newey-West). (ln) indicates a variable that enters in logarithmic specification. ML stands from mega litres. Each regression contains month and day of the week dummies and the complete set of weather controls described in Section 4.

Columns 3 tests robustness to the inclusion of a time trend. The time trend is statistically insignificant and there is negligible change in any of the coefficients except for an increase in price elasticity. Column 4 adds a lagged dependent variable directly addressing the observed serial correlation evident in the errors. Though the coefficients change, the implied long-run effects of all our coefficients of interest are very stable.[23] Finally column 5 restricts the sample to the stage 3 restriction period, thereby excluding the initial rapid decrease in both dam level and consumption at the start of our sample. Once again the coefficients are robust.

The economic literature on demand management has paid significant attention to the estimation of price elasticities. Both average cost and marginal cost have been argued to be appropriate price variables. Additionally, since we are using aggregate data, arguments could be made for the use of either average marginal cost or marginal cost faced by the average user. Table 4 shows that although the estimated price elasticities themselves vary substantially, the coefficient on dam level is robust. Interestingly, and somewhat reassuringly, the average price elasticity of -0.50 is close to the implied total price elasticity of -0.47 from our base regression.

Table 4. Robustness to price measure

	(1) Per capita use (ln)	(2) Per capita use (ln)	(3) Per capita use (ln)	(4) Per capita use (ln)
Dam level in %	0.00553***	0.00500***	0.00550***	0.00674***
	(4.45)	(4.34)	(4.64)	(4.99)
Marginal cost (ln)	-0.200***	-0.121***		
	(-5.72)	(-4.62)		
Marginal cost low users(ln)	-0.272***			
	(-5.32)			
Average cost (ln)			-0.507***	

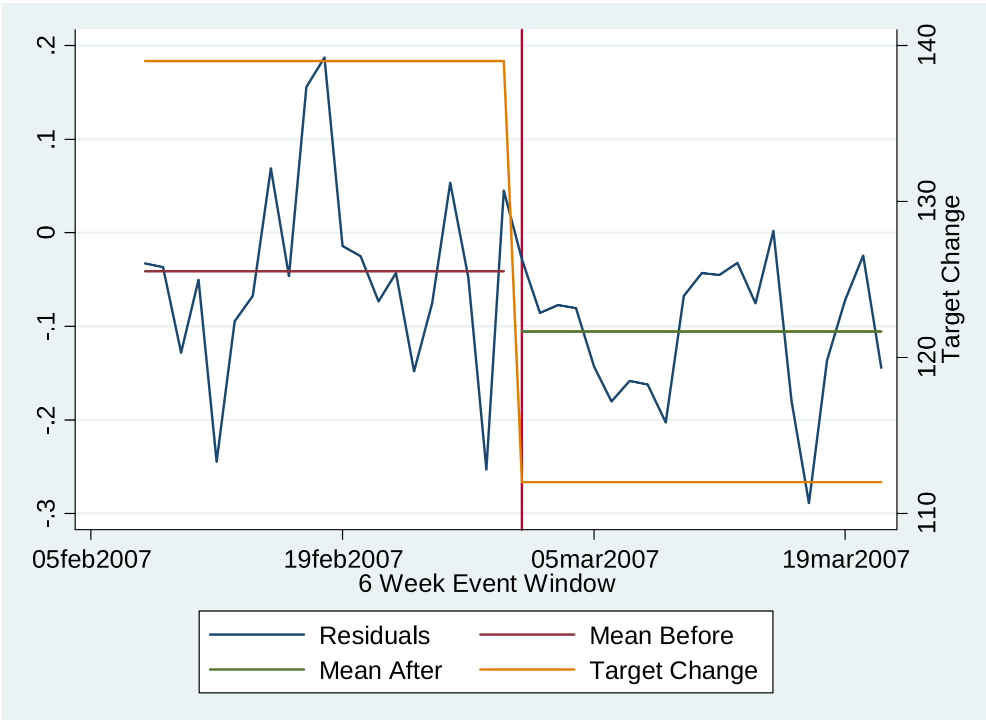
[23] The variable coefficients in the regression of column 4 represent the short-run same period effect. To get the comparable long-run effect of a variable we need to divide the coefficient by (1 - lagged dependent variable coefficient). So the long-run effect of dam levels in the distributed lag model of column 4 is 0.00255/(1-0.545)=0.0056.

			(-5.98)	
Average marginal cost (ln)				-0.336***
				(-5.54)
Stage 1 restrictions	0.0710*	0.169***	0.0781**	0.0783*
	(1.73)	(5.82)	(2.00)	(1.90)
Stage 2 restrictions	0.114***	0.151***	0.121***	0.116***
	(4.60)	(6.55)	(5.04)	(4.64)
Summer exemption	-0.0383	-0.0497*	-0.0360	-0.0391
	(-1.52)	(-1.79)	(-1.40)	(-1.52)
Spring clean	-0.0367	-0.0261	-0.0294	-0.0328
	(-1.20)	(-0.92)	(-0.98)	(-1.13)
Observations	1539	1539	1539	1539
Adjusted R^2	0.886	0.879	0.886	0.884

Notes: t statistics in parentheses: $^{*}p<0.1$, $^{**}p<0.05$, $^{***}p<0.01$. Standard errors are heteroskedasticity and autocorrelation consistent (Newey-West). (ln) indicates a variable that enters in logarithmic specification. ML stands from mega litres. Each regression contains month and day of the week dummies and the complete set of weather controls described in Section 4.

Now we turn the results of our event study design. Figure 3 presents an event study result for a downward shift in the target from 139 ML to 112 ML as it took place from summer to autumn 2007. The graphs shows the unexplained variation in water usage after we control for weather and other month and day effects and any other variables that change during the event window. The blue line is the daily error term of our main specification column 3 in Table 2. We observe them here for an event window of three weeks before and after target change. The green and red lines present the means of the 3 week before and after period. And the yellow line shows the direction of the target change. The horizontal line marks the target change event. Inferring from this graphical representation we might conclude that there is an effect of the target change on consumption. When tested the small reduction is not significant.

Figure 3. Event Study Results



Such a graph and test are run for each target change in our sample during the consistent stage 3 restriction scheme. We include all event window graphs in the Appendix. The test statistics for all events are summarized in Table 3. The null hypothesis of the abnormal water consumption being equal before and after the target shift cannot be rejected for any of the individual target shifts. The joined test across all events using robust standard errors can also not be rejected. With a p-value of .706 we find that the cumulative `abnormal' water consumption differences around the target changes are not significantly different from zero. We were also unable to reject the null of no significant difference when the event window was shortened to one or two weeks either side of the target change. Thus we conclude that changes in target levels did not have an appreciable direct effect on people's water consumption.

Table 3. Event Study Test Results (targets in ML per day)

Year	2007	2007	2007	2007	2008	2008	2008	2008	2009	2099	2009	2009
Target Change:	139-112	112-97	97-112	112-139	139-112	112-97	97-112	112-139	139-112	112-105	105-120	120-150
t-stat	-.667	.263	.210	-.681	.974	-.255	.223	.405	-.166	.330	-.607	.103

Notes: Each t-statistic is from a two sided test with the null hypothesis of the `abnormal' water consumption being equal before and after the target change. The critical value at the 10% level is 1.65.

6. Conclusion

Information campaigns are almost universally used by water managers in times of short supply and survey evidence suggests that they are effective at changing conservation behaviour. The econometric literature to date, however, has been unable to identify substantial demand reductions following these campaigns.

We use a novel approach to identifying voluntary behavior through demand response to changes in dam level for a population which was exposed to a long-term awareness campaign which emphasized community responsibility for dam-levels. We find dam level is significantly and robustly correlated with consumption. The magnitude of the effect is such that the dam level change from 60% to 30% in our sample is estimated to have resulted in demand reduction of around 15%.

We view our results as evidence that, among a well-informed population, voluntary conservation can make a substantial contribution to demand reductions precisely when the need for them is greatest. While our findings by no means prove the efficiency of information campaigns as a demand management tool, we do think they call into question the conclusion from the bulk of the econometric studies that information campaigns are ineffective. Further research on the efficacy of information campaigns seems warranted, particularly on the interaction between education, price, and mandatory restrictions. In light of the ongoing push for a greater reliance on price as a means of allocating scarce urban water supplies,[24] it also seems pertinent to ask whether this "commoditization" of what has traditionally been viewed as a right or common property resource[25] may lead to a decline in voluntary conservation.

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[24] See for example Olmstead & Stavins (2009); Grafton & Ward (2008)

[25] See for example Page (2005); Bakker (2007)

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Appendix

Details of Water Restrictions

	Stage 1	Stage 2	Stage 3	Summer exemption	'spring clean'
Lawns	Restricted times[26], sprinkler allowed	Restricted times, no sprinklers	No	Weekends; sprinklers 7pm-10pm	No
Gardens	Sprinkler: restricted times, trigger nozzle hose, can or bucket: any time	Restricted times; no sprinklers, only trigger nozzle hose, can or bucket	Restricted times, no sprinklers, only trigger nozzle hose, can or bucket	Restricted times, no sprinklers, only trigger nozzle hose, can or bucket	Restricted times, no sprinklers, only trigger nozzle hose, can or bucket
Vehicles	Wash on lawn once a week, only trigger nozzle hose, can or bucket	Wash on lawn once a month, only trigger nozzle hose, can or bucket	No washing except at commercial carwash with recycled water	No washing except at commercial carwash with recycled water	Wash on lawn, only trigger nozzle hose, can or bucket
Fountains	Only if uses recirculated water, refill only with trigger nozzle hose, can or bucket	Must be switched off	Must be switched off	Must be switched off	Must be switched off
Ponds	May only be topped up with trigger nozzle hose, can or bucket	May only be topped up with trigger nozzle hose, can or bucket	May only be topped up if support fish	May only be topped up if support fish	May only be topped up if support fish
Pools	Filled: no emptied: no topped up: yes	Filled: no emptied: no topped up: yes	Must not be emptied, filled or topped up	Must not be emptied, filled or topped up	Must not be emptied, filled or topped up
Windows/ buildings	May be washed but not with a hose	No washing unless health hazard	No washing unless health hazard	No washing unless health hazard	May be washed but not with a

[26] 'Restricted times' refers to 7am-10am and 7pm-10pm on alternate days according to the "odds and evens" system.

					hose
Paved areas	No washing	No washing	No washing	No washing	Washing permitted

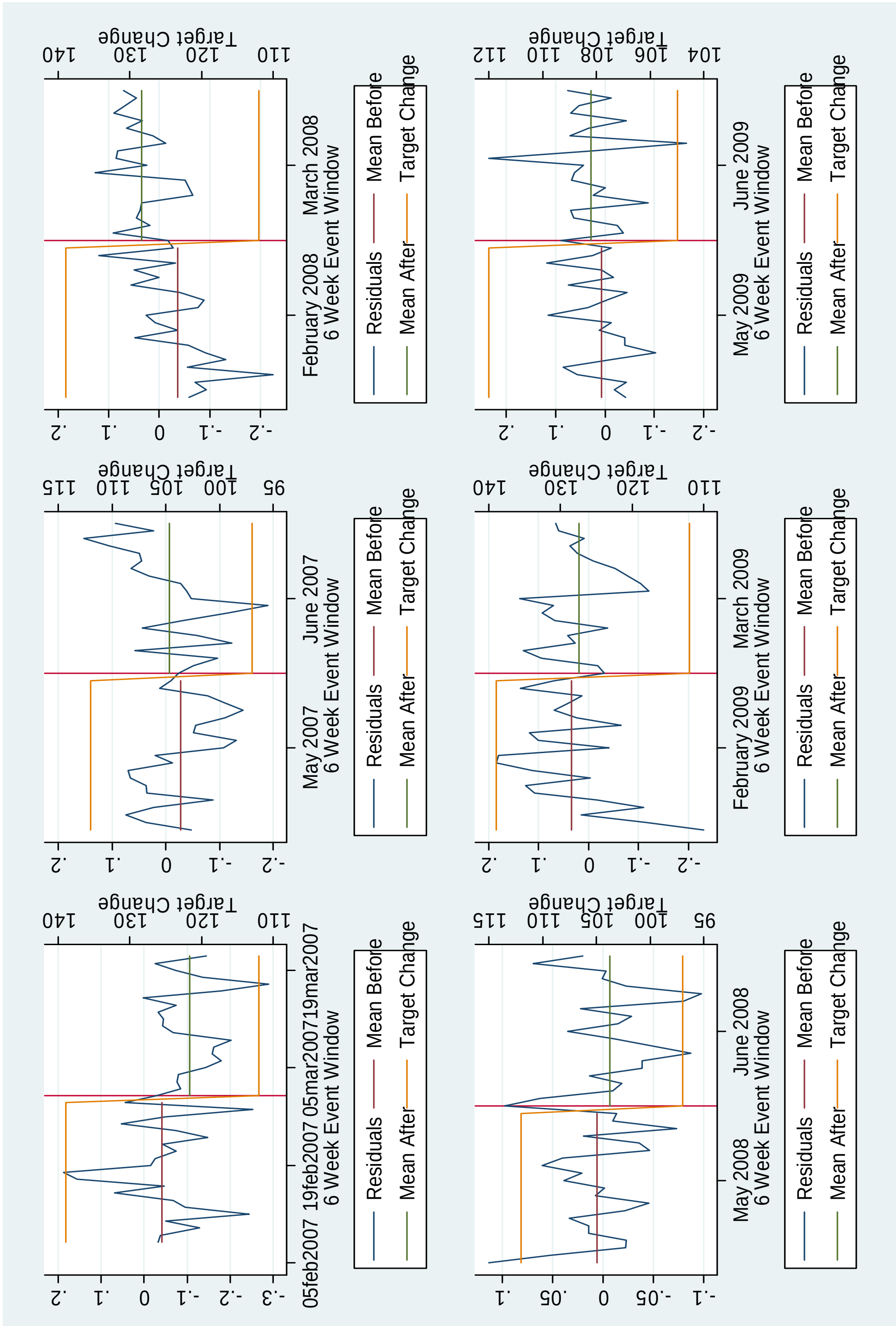

Figure 4. Event Graphs for Downward Shifts of the Water Use Target

Figure 5. Event Graphs for Upward Shifts of the Water Use Targets