REPORT

Title Evaluating the Efficacy of a Long-Term Residential Water Conservation Program in College Station, TX.

Project Number 2015TX482B

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Abstract

This research details the evaluation of water savings associated with the administration of an information-based residential demand management policy in College Station, TX. The authors draw on a quasi-experimental design to attribute a causal effect to the treatment. The results indicate that the information-based program was successful in reducing the water use of households that received messages, and that the savings increase over time with each repetition of the messages. However, heterogeneity exists in the treatment effect based on household baseline water use (e.g., in the period before the messages were administered). The results are discussed in the light of developing effective residential demand management policy, and changing consumer behaviors.

Problem and Research Objectives

Background

Conservation has been identified as a critical component of ensuring an adequate future water supply in the state of Texas (Water for Texas, 2012). However, beyond stressing the potential contributions of conservation in closing anticipated gaps in supply and demand, the exact mechanisms through which to achieve these needed reductions in water use remain poorly defined. The residential sector is one area where significant reductions in water use stand to made. The Environmental Protection Agency (2013), for instance, estimates that as much as half of all the water used outdoors, for lawn and landscaping irrigation, is wasted as a function of leaking infrastructure, over watering, and miss-direction. Improving the efficiency of water use in lawn and landscaping irrigation, therefore, can result in significant water savings (Endter-Wada et al., 2008; White et al., 2004).

Achieving these potential reductions in water use requires upgrades in technology, but potentially more importantly, significant changes in the behaviors of water users (Schultz et al., 2014; Schultz, 2011). In an attempt to manage demands for outdoor water, and leverage behavior change among water customers, utility mangers have designed and implemented a host of policy interventions (Olmstead and Stavins, 2009; Kenney et al., 2008; Campbell et al. 2004). These interventions range from progressive block rate price structures and financial incentives for technical retrofits (Arbúes et al., 2004), to persuasive educational messages and public information campaigns that stress the merits of conservation (Syme et al., 2000). Although the savings associated with conservation pricing structures and technological upgrades are relatively well understood in the literature, the potential savings associated with information-based instruments are context specific and comparatively understudied (Syme et al., 2000). Evaluating the ability of information-based instruments to reduce water use and change the behaviors of residential water users, however, is necessary in order to meet long-term goals for water use, water supply, and conservation in the residential sector. This is especially important given that information and education polices are among the most commonly employed strategies in municipal conservation programs (Mickelson et al., 2000). Additionally, market based mechanisms are infeasible in many communities owing to the political climate and the social acceptability of rate increases.

Over the last several years, water managers in the City of College Station Texas have undertaken a residential demand management campaign featuring a number of the policy instruments mentioned above including block rate pricing structures, rebates for technological upgrades, audits of irrigation systems, and especially persuasive educational messages designed to improve the efficiency of outdoor water use within the service area.

Research Objectives

The objective of this research was to determine the water savings associated with the persuasive information-based messages implemented as a part of the College Station residential water conservation program. This educational program has consisted of providing personalized feedback on water use to a subset of the city's largest consumers of water in the form of a "water budget". The water budget is composed of two key pieces of information, 1) a comparison of the customers' water use to an "efficient" standard determined as a function of their lawn's water needs and climatic conditions, and 2) a comparison of their water use to the water use of their neighbors. These comparisons, along with accompanying information on how to reduce outdoor water use, are designed to give customers a benchmark against which to judge their behavior, and when appropriate conform to societal expectations regarding water use (Shultz et al., 2014; McKenzie –Mohr, 2000; Cialdini et al. 1990; Festinger, 1954). Although the impacts of general conservation education programs have been reported with mixed success in the literature (Schultz et al., 2002; Michelsen et al. 2000), social norms and social marketing approaches (McKenzie-Mohr, 2000), like the one implemented here, have shown promise in achieving behavior change among resource users (Schultz et al., 2014).

Materials/Methodology

Description of the water budget program

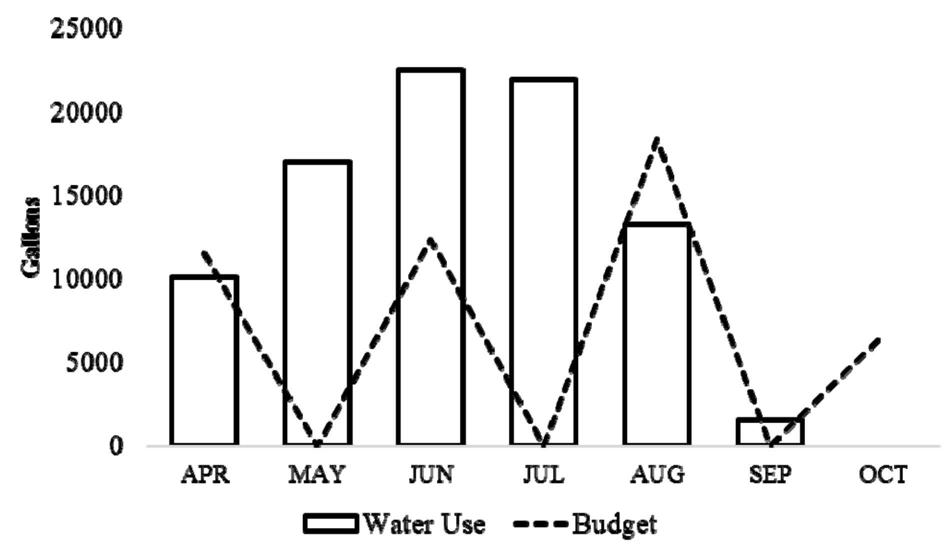
Households were selected for inclusion in the water budget program (e.g., receive the communications) if they were located in a neighborhood with average household irrigation season (April to October) water use in excess of 100,000 gallons, during the period 2008-2011. All households in the neighborhood received the communication if the neighborhood fell under this condition, regardless of their individual consumption. Households in these neighborhoods (n=5,565) have received the water budget communication at the beginning of the irrigation season each year since 2012. An example of the water budget graph presented to participants is shown in Figure 1. The solid bars represent household water use for that month, and the dotted line represents the water budget, or what would have been an efficient application (e.g., enough to keep their lawn healthy) of irrigation water given the climatic conditions during that period of time. Water budgets are provided at a one year time lag. For example, at the beginning of the 2014 irrigation season households received feedback on their 2013 water use.

Following White et al. (2004) the water budget was calculated as a monthly water balance of precipitation and evapotranspiration over a given area of lawn:

$$\textbf{Eq. 1.}\ WB\ (gal)_{\ month} = \text{Irrigable Area } (ft^2) * [(K_c * PET\ (in) - P\ (in))] * .6\ (gal/ft^2)$$

Where WB is the monthly water budget in gallons, Irrigable Area is the area of the household parcel subject to irrigation (derived from GIS files), K_c is a crop coefficient, PET is potential evapotranspiration in inches, P is precipitation in inches, and .6 is a conversion factor of inches to gallons. Social comparisons (not pictured) were conducted at the neighborhood scale for both total outdoor water use per square foot of lawn, and neighborhood water use compared to the budget.

Figure 1. Example Water Budget Graph



Analysis

To assess the efficacy of the water budget program we drew on monthly household water use records for the City of College Station spanning from 2008 to 2014 (n=8,816). Our analysis was limited to single family detached homes with complete water use records spanning the length of the study. We used a fixed-effects difference-in-difference approach to compare the monthly irrigation season water use between households that received the water budget communications to those that did not, in the periods before (2008-2011) and after (2012-2014) they were administered. We limited the pseudo control group (e.g., households that did not receive the messages; n=4,561) to the same range of demographic characteristics as the treatment group (e.g., households that received the communications; n=4,255) including lot size, home value, and home age drawn from publicly available county tax assessment records, in order to ensure the validity of the comparisons. To account for unobserved household level variables influencing demand we estimated a fixed-effect for each household. We also controlled for monthly climate variables, including total precipitation and average daily maximum air temperature, which have been shown to influence demand (Arbúes et al., 2003). Climate data were drawn from a combination of three weather stations operational at different periods of time (from 2008-2014) within the city. Monthly household irrigation season water use was modeled following:

Eq. 2. $$WU_{it} = \beta_1 P_t + \beta_2 T_t + \beta_3 TG_i + \beta_4 TP_t + \beta_5 TG_t * TP_t + a_i + u_{it}$$

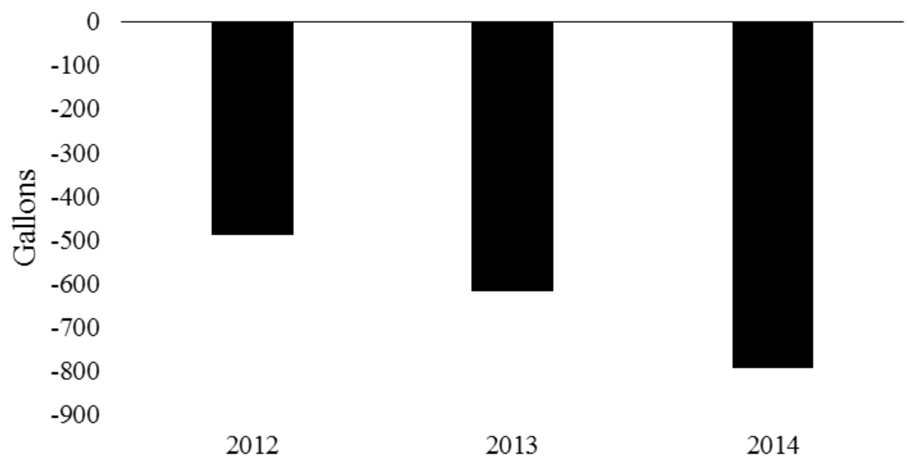
Where WU is monthly household water use, P is total precipitation in month t, T is average daily maximum air temperature in month t, TG is a dummy variable representing the ith household's membership in the treatment group, TP is a dummy variable representing months during the treatment period, and TG*TP is an interaction of treatment group and treatment period which yields the difference-in-difference estimate (treatment effect), a_i and u_{it} are error terms.

In addition to estimating the total water savings attributed to the program we conducted additional analyses to determine changes in the strength of the treatment effect over time, and variation in the treatment effect by the level of baseline household water use (e.g., pre-2012), split into roughly equal thirds. To do this we ran separate models to estimate a treatment effect for each year of the program 2012, 2013, and 2014, and for each year by each of the three water use groups (e.g., bottom 33% of households, middle 33% of households, and top 33% of water using households). We hypothesized that the treatment effect would be strongest among the top water using households, and have little or no effect on the bottom two thirds.

Principal Findings

Results indicate that the water budget program yielded an average monthly reduction in household irrigation season water use of 649 gallons ($t=-6.49$, $p<.001$). Over the course of the program 2012 – 2014 this amounts to a savings of roughly 76 million gallons, or 233 acre feet, for the entire treatment group (n=5,565). However, there was quite a bit of heterogeneity in the strength of the treatment effect over time. Our results demonstrate an increased strength in the treatment effect each year with repetition of the water budget messages (Figure 2). In 2012 the estimated water savings associated with the water budget program were 489 gallons per household per month ($t=-4.56$, $p<.001$), 618 gallons per household per month in 2013 ($t=-5.20$, $p<.001$), and 794 gallons per household per month in 2014.

Figure 2. Average Monthly Household Reduction in Water Use due to Water Budget Program 2012-2014



Similarly, we found significant variation in the treatment effect by water use groups (Figure 3). Households that fell in the top one third of water using households in the period before the water budget program began, exhibited the largest reductions in water use; 2,659 gallons per household per month (t=-15.74, p<.001). Households falling within the middle one third of water users during the baseline period exhibited limited response to the water budget messages, reducing their consumption by an average of 307 gallons per month (t=-2.52, p<.001). Last, households falling within the bottom one third of water users actually responded to the water budget messages by increasing their consumption, on average 1,220 gallons per month (t=11.39, p<.001). This was an unexpected result. However, past work in the psychology and economics literatures has demonstrated that social norms messages can cause increases in undesirable behaviors when respondents are below the norm that they are being compared to, and the message that they receive does not adequately demonstrate the acceptability of being below the norm (Schultz et al., 2007; Alcott, 2011). This is referred to as the "boomerang effect", and has implications for the use of social norms messages in resource conservation. Similar to results for the entire treatment group, treatment effects increased in strength for each of the water use subgroups over time (Figure 3).

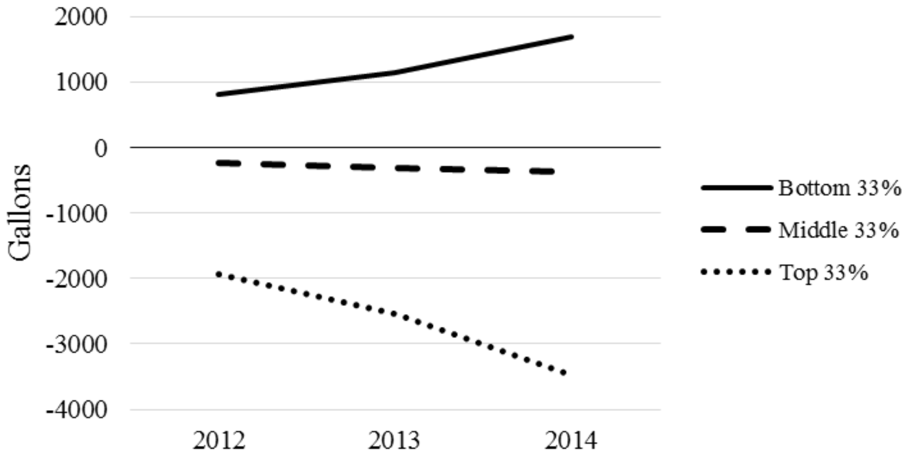


Figure 3. Average Monthly Household Reduction in Water Use due to Water Budget Program 2012-2014 by Water Use Group

Significance

The results of this work have implications for the administration of education and information-based policy instruments in residential demand management. First, we empirically demonstrate that information-based messages can indeed influence the water use behaviors of residential consumers. Our results parallel other studies that have used a similar social norms based approach (Ferraro and Price, 2013). However, this is one of only a few studies to demonstrate that the effects of norms-based messages can increase with message repetition over time. Future work should seek to examine the cost effectiveness of information-based messages, and determine ceiling effects in their ability to influence consumer behavior. Second, we found differential effects on water savings based on household initial water use. In fact, the lowest users actually increased their consumption. Conservation programs seeking to influence consumer behaviors through social norms approaches, like the on detailed here, must be careful to construct messages in a way that make expectations clear, and consider carefully who the messages are sent to. Our results, for instance, indicate that the program would have yielded greater savings, and cost less to administer, if the bottom one third of consumers did not receive the messages at all.

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