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Low-flow appliances and household water demand: An evaluation of demand-side management policy in Albuquerque, New Mexico

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ABSTRACT

Residential rebate programs for low-flow water devices have become increasingly popular as a means of reducing urban water demand. Although program specifics vary, low-flow rebates are available in most U.S. metropolitan areas, as well as in many smaller municipalities. Despite their popularity, few statistical analyses have been conducted regarding the effects of low-flow rebates on household water use. In this paper, we consider the effects of rebates from the Albuquerque Bernalillo County Water Utility Authority (ABCWUA). Using panel regression techniques with a database of rebate recipients, we estimate the marginal effects of various low-flow devices on household water demand. Results indicate a negative correlation between household water use and the presence of most low-flow devices, after controlling for water price and weather conditions. Low-flow toilets have the greatest impact on water use, while low-flow washing machines, dishwashers, showerheads, and xeriscape have smaller but significant effects. In contrast, air conditioning systems, hot water recirculators, and rain barrels have no significant impact on water use. We also test for possible rebound effects (i.e. whether low-flow appliances become less-effective over time due to poor rates of retention or behavioral changes) and compare the cost effectiveness of each rebate using levelised-costs. We find no evidence of rebound effects and substantial variation in levelised-costs, with low-flow showerheads being the most cost-effective device under the current ABCWUA rebate program. The latter result suggests that water providers can improve the efficiency of rebate programs by targeting the most cost-effective devices.

1. Introduction

Scarce water resources, particularly in semi-arid regions of the United States, are increasingly strained by population growth, economic development, and drought. A major challenge for urban and regional planners is to ensure sufficient resources are available to meet projected demand—and to balance these resources between competing uses (e.g. agriculture, residential, commercial, and industrial). In addressing this challenge, municipal water providers have emphasized the need to reduce residential water use, which accounts for approximately 58% of urban consumption (Barber, 2009).[1] Specifically, water providers have turned to demand-side management as a means of reducing per-capita water demand (Arbués and Villanúa, 2006; Michelsen et al., 1999).

Previous literature distinguishes between two types of demand-side management: price and non-price policies (Kenney et al., 2008; Krause et al., 2003). Price policies refer to various price structures, most commonly block-rates, used to incentivize water conservation. The effectiveness of these policies largely depends on the price elasticity of water demand. Recent empirical studies indicate that the price elasticity of demand for water is inelastic at current prices, implying that price increases result in only modest declines in the quantity demanded (Arbués et al., 2003; Dalhuisen et al., 2003). Partially due to this inelasticity, water providers have predominantly utilized non-price policies (Olmstead et al., 2007). Non-price policies refer to a wide range of interventions, including: restrictions on water use, public education campaigns, subsidies for low-flow appliances, and low-flow engineering requirements on new plumbing fixtures. Among the more popular non-price policies are rebate programs for low-flow appliances (e.g. toilets, showerheads, and washing machines). At present, rebate programs can be

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[1] In addition to conservation, reducing residential water use mitigates the need for costly investment in capital stock (e.g. water treatment, infrastructure repair, and system expansion). On average, municipal water providers invest 40% of annual gross revenue in capital stock (EPA, 2006).

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found in most metropolitan areas, as well as in many smaller municipalities.[2] Programs in Austin, Los Angeles, New York, Phoenix, and Tampa distributed nearly 2.3 million low-flow toilets between 1992 and 2000 (U.S. General Accounting Office, 2000). These programs cost $400 million and reduced water consumption by approximately 100 million gallons per day (U.S. General Accounting Office, 2000).

Despite the popularity of rebate programs, few statistical analyses have been conducted regarding their impact on household water use—and questions remain as to their success. Of particular interest is whether actual water-use reductions brought about by low-flow appliances resemble those predicted by engineering estimates. These values may differ if low-flow appliances prompt behavior changes that mitigate or enhance the expected reduction. A related concern is whether the effects of low-flow appliances diminish over time due to poor rates of retention (i.e. the low-flow appliance is replaced) or changing behavior. Finally, given the considerable costs associated with rebate programs, it is of interest to identify the most cost-effective rebates.

In the following analysis, we address these questions using monthly water-use and rebate data from the Albuquerque Bernalillo County Water Utility Authority (ABCWUA). We estimate the marginal impact of various low-flow appliances on household water use, after controlling for the price of water and weather conditions. Results from the analysis contribute to public understanding of conservation programs and offer practical guidance for water providers developing demand-side management policies.

2. Background

2.1. Water demand in Albuquerque, NM

The ABCWUA delivers water to nearly 520,000 residents in the Albuquerque metro area (ABCWUA, 2011). Until recently, the city relied exclusively on groundwater obtained from the Santa Fe Group aquifer—a vast aquifer system that extends throughout the Middle Rio Grande Basin. During the early 1990s new hydrologic research revealed that the aquifer contained considerably less water, and that replenishment rates were lower, than previously believed. Recognizing that current water use patterns were unsustainable, the city of Albuquerque moved to develop methods of surface water extraction and treatment (Bartolino and Cole, 2002). In 2008, the San Juan-Chama Project began diverting and purifying water from the Rio Grande. This project, which required $400 million in new infrastructure, will eventually supply 90% of Albuquerque's water demand (ABCWUA, 2011).[3]

Water demand in Albuquerque, largely driven by population growth, increased steadily throughout the 20th century (Gutzler and Nims, 2005). At its peak in 1995, total annual consumption for the Albuquerque metro area was 40.7 billion gallons. Per capita consumption during the same year was 251 gallons per day. In 1995 the city initiated a comprehensive water conservation program. This program included public education campaigns, price increases, low-flow rebates, and outdoor watering restrictions. Since implementation of these programs water use has declined substantially, despite continued population growth. According to ABCWUA estimates, total water demand fell by 16%, and per capita demand by 38%, between 1996 and 2009 (ABCWUA, 2010). By 2009 an estimated 155 billion gallons of water had been saved as a result of conservation measures (ABCWUA, 2010). Gutzler and Nims (2005) provide further evidence of the success of these measures. They evaluate the effect of climate variability on Albuquerque's water demand between 1980 and 2000. Results indicate that climate conditions have not contributed to the sharp decline in residential water demand, suggesting instead that behavioral and technological changes are the primary drivers.

In addition to annual changes, Albuquerque exhibits considerable seasonal variation in water demand. Residential demand, which accounts for 61% of ABCUWA water deliveries, is the primary source of these variations (ABSUWA, 2010).[4] Increased use of landscape watering and evaporative cooling systems during the summer months lead to peak demand that is nearly three times the winter minimum (Gutzler and Nims, 2005). Surprisingly, Albuquerque's conservation policies appear to have had little impact on seasonal variation. Gutzler and Nims (2005), using city level data and controlling for climate conditions, find no difference between the magnitude of seasonal variation during pre- and post-conservation periods. It is worth noting that this finding, while true for total Albuquerque water use, does not hold for individual households. A cursory examination of data used for this analysis indicates that seasonal variation decreased significantly for households that received rebates for improved landscaping.

2.2. Rebate program

Low-flow rebates have been a key component of the ABCWUA demand-side management strategy since conservation measures began. The ABCWUA divides rebates into three categories: indoor, outdoor and xeriscape. Currently, indoor rebates are available for several low-flow appliances: toilets, showerheads, hot water recirculation systems, washing machines, and evaporative cooler thermostats.[5] Rebates for dishwashers and air conditioners were introduced in 2003, but both have since been discontinued. Outdoor rebates are currently available for sprinkler controllers, grass removal equipment, rain sensors, and rainwater harvesting systems. Xeriscape rebates are available for converting high water-use landscape to xeriscape. The xeriscape rebate is paid per ft^2 of converted area.

Table 1 presents information on the availability, value, and number of recipients for each rebate evaluated in this analysis. The rebates labeled LFT1, LFT2 and LFT3 refer to households that have received a 1st, 2nd and 3rd low-flow toilet rebate, respectively. Also included are rebates for showerheads (SW), washing machines (WM), rain barrels (RB), hot water recirculation systems (HWR), air conditioners (AC), dishwashers (DW), and xeriscaping (XS). Rebate values are occasionally adjusted by the ABCWUA; the amounts reported in Table 1 indicate the range of values offered since 1995. The largest rebates are for air conditioners ($500) and toilets ($200), while the smallest are for showerheads ($10) and xeriscape ($0.75 per ft^2 of converted area). The number of rebate recipients varies considerably. The most popular rebates are toilets (43,046), washing machines (19,342), showerheads (9209), dishwashers

[2] The Environmental Protection Agency (EPA) maintains a partial list of rebate programs in the U.S. and Canada at http://www.epa.gov/WaterSense/rebate_finder_saving_money_water.html. More than 115 cities offer low-flow appliance rebates.

[3] The ABCWUA is also developing plans to artificially recharge the aquifer (ABCWUA, 2010). Artificial recharge is part of a process know as Aquifer Storage and Recovery that allows water to be stored without depletion from evaporation.

[4] By comparison commercial, industrial and institutional demand account for 15%, 1% and 10% of water deliveries, respectively. Gutzler and Nims (2005) find that non-residential demand exhibits weak seasonal variability.

[5] Hot water recirculation systems circulate water in hot-water pipes, thus providing instantaneous hot water to each faucet. This greatly reduces the amount of water used waiting for hot water to travel from the heater to the faucet. Evaporative coolers are devises, typically used in dry climates, which cool air through the evaporation of water. Thermostats automatically turn off the evaporative cooler once the desired temperature has been reached.