# MUNICIPAL REBATE PROGRAMS FOR ENVIRONMENTAL RETROFITS: AN EVALUATION OF ADDITIONALITY AND COST-EFFECTIVENESS

Lori S. Bennear, Jonathan M. Lee and Laura O. Taylor[1]

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*Abstract:*
Rebate programs have become a common conservation policy tool for local municipalities seeking to retrofit residential properties with efficient appliances. This research evaluates whether such rebates can be cost-effective means for water utilities to promote water conservation. A unique database is developed that combines water use data over a three-year period for all households that participated in a utility's high efficiency toilet (HET) rebate program, water use data for a matched sample of neighbors who did not receive a rebate, and a survey of rebate participants. Difference-in-differences models indicate that installation of a HET reduces household water consumption by approximately 7%. While *installation* of a HET appears to be an effective means for achieving household reductions in water consumption, our results also suggest that the *rebate program* is a much less effective means for achieving household reductions in water consumption. Specially, the rebate program is found to provide limited additional water savings beyond what would have occurred naturally and is responsible for only 37% of the total water reduction attributable to the installation of HETs over the study period.

Keywords: rebate programs, water efficiency, difference-in-differences estimator, cost-effectiveness

JEL Codes: Q25, Q28, H76

[1] *Bennear*: Assistant Professor, Nicholas School of the Environment, Duke University, lori.bennear@duke.edu
*Lee*: Assistant Professor, Department of Economics, East Carolina University, leejo@ecu.edu
*Taylor (corresponding author)*: Professor, Department of Agricultural and Resource Economics, Director, Center for Environmental and Resource Economic Policy, North Carolina State University, laura_taylor@ncsu.edu.

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## 1. Introduction

While price may still be economists' preferred method for signaling scarcity, many utilities (both water and energy) are increasingly relying on non-price programs to manage demand. A popular approach to demand management is to subsidize energy- or water-efficient appliance adoption through the use of rebate programs. Rebate programs typically refund part or all of the cost of the appliance and installation. While no comprehensive list is available, the U.S. Environmental Protection Agency (EPA) lists over 100 rebate programs for water-efficient appliances across the country, the vast majority of which focus on rebates for installation of high efficiency toilets (HETs).[2] In the U.S., toilets are the largest single source of indoor water use, accounting for almost 30% of a household's indoor water use, on average.[3] Although rebate programs for HET installation are offered to millions of households across the U.S.,[4] we are unaware of attempts to quantify their effectiveness as a water conservation tool for utilities.

Engineering estimates suggest significant water savings are possible with bathroom retrofits. For example, the U.S. EPA suggests that replacing all the pre-1990 model toilets in a household with high efficiency toilets can reduce water usage for a family of four by between 16,000 and 27,000 gallons per year, depending on the age of the toilet replaced.[5] However,

[2] Rebate programs are available at: http://www.epa.gov/WaterSense/rebate_finder_saving_money_water.html
[3] U.S. Environmental Protection Agency, "Indoor Water Use in the U.S.," available at: http://www.epa.gov/WaterSense/docs/ws_indoor508.pdf, last accessed October 4, 2011.
[4] For example, the California Water Service Company alone, which includes 21 districts serving over 460,000 customers, lists a rebate program for high-efficiency toilets in all 21 of its districts. See http://www.calwater.com/conservation/rebates_residential.php, last accessed October 4, 2011.
[5] The US EPA's watersense calculator and a description of the methods used can be found at: http://www.epa.gov/watersense/our_water/be_the_change.html#tabs-3, last accessed July 15, 2012.

rebates may not be as effective at reducing water use as engineering estimates suggest because some of these retrofits may have occurred even in the absence of the rebate program. To the degree that a rebate is given to a household *after* their decision to replace an old appliance with a high-efficiency one, the rebate represents a windfall gain to the household rather than an expenditure on demand-side management of water resources. We are not aware of any evidence measuring the additionality of rebate programs – i.e., measuring the degree to which rebates have induced the household to replace old appliances (toilet or other) that would not have been replaced otherwise.[6]

Our research seeks to quantify the additionality of rebate programs and determine if they can be a cost-effective means for water utilities to promote water conservation. To accomplish this, we partner with a water utility in North Carolina to develop a unique database of 683 households that participated in a rebate program for HET retrofits that combines three-and-a-half years of household water use data with a survey to determine the household's motivation for replacing their old toilets. In addition, monthly water-use data is gathered for a matched sample of 25,100 households that neighbor rebate households and that did not participate in the program. Difference-in-differences (DID) models are estimated to provide estimates of the water savings associated with HET *installation*. The DID models are then combined with survey information on each household's motivation for replacing their old toilet to compute the additional water savings that can be attributed to the *rebate program* above what would have occurred due to natural replacement of older appliances.

Results suggest that replacing a pre-1991 toilet with a HET results in significant reductions in household water consumption of 7%, or 3,612 gallons per year. This estimate is

[6] Joskow and Marron (1993) provide an early discussion of additionality, and other concerns, when evaluating how electric utilities have calculated the cost-effectiveness of their demand-side management programs.

quite similar to an engineering estimate of water savings that would result from replacement of the old toilets in our sample with HETs.[7] While the *installation* of a HET appears to be an effective means for reducing household water consumption, the *rebate program* is a much less effective means for achieving household reductions in water consumption. Our results suggest that only 37% of the water savings associated with HET installation can be directly attributed to the rebate program. In other words, 63% of the water savings would have occurred even in absence of the rebate program because the rebate induced very few households to replace a toilet that they weren't already planning on replacing.

Given the limited additionality of the rebate program, the cost-effectiveness from a utility manager's viewpoint is also limited. We estimate that the utility spent approximately $11 to $15 per 1,000 gallons conserved via the rebate program, depending on assumptions about the proper discount rate and the length of time it takes before a household naturally replaces an older toilet (these assumptions are further discussed in Section 4). While the evidence on the cost-effectiveness for other similar types of conservation programs is limited, hindering relative comparisons across programs, the cost-effectiveness of HET subsidies can be compared to the utility's alternative to demand management: capacity expansion. Currently the utility estimates new capacity expansion will cost approximately $7 per 1,000 gallons. In this comparison, the rebate program fares poorly as a management tool.

On a more positive note, the robust water savings attributable to *installation* of a HET suggests more direct targeting for HET replacement incentives by utilities could be quite cost-effective. For example, if a rebate expenditure of $150 is 100% additive, our DID estimates of

[7] Our estimates are significantly lower than that provided by the US EPA's watersense calculator for the water savings associated with replacing toilets in an average-sized home. The primary difference is because the EPA calculator assumes all toilets in a household are replaced. Our observational data indicates that this is typically not the case.

water savings per HET installed in a residential setting imply a cost-effectiveness of $4 to $5 per 1,000 gallons conserved. Ensuring full additionality may be difficult to achieve, but could be promising in situations such as direct subsidization of toilet replacement for multi-metered residential complexes in which renters pay their own water costs.[8]

The remainder of this paper is as follows. Section 2 describes the rebate program examined in this study, the survey that was administered to households receiving a rebate, and the water-use data available for analysis. Section 3 outlines the difference-in-differences estimation strategy, provides results and includes robustness and specification checks. Section 4 explores the cost-effectiveness of the rebate program and Section 5 concludes.

## 2. Program Background and Data

We use a unique database of 683 households that installed 1,195 high efficiency toilets in Cary, North Carolina. Cary is adjacent to Raleigh, the State capital, and has a population of over 130,000 that is served by a single water utility owned by the township. Cary introduced its HET Retrofit Rebate program in June 2008. Our data are from the first two years of the program. During this time, all residents of Cary had the opportunity to apply for a rebate on a qualifying HET purchase and installation. The rebate was advertised in many locations including the utility newsletter mailed with customers' water bills, the town's website, the Cary newspaper that is delivered once per week to all households in Cary free of charge, the Raleigh News & Observer, and at the point-of-sale in local outlets of national home improvements stores.

[8] We find it unlikely that renters will invest in high-efficiency water appliances given the relatively long pay-back period relative to rental tenure. Further, the incentive of apartment owners to invest in water efficient appliances is diminished to the degree that rental rates are not adjusted to reflect differences in water costs for the renter – a situation we find likely given the relative small proportion of total utilities that most water bills comprise for renters.

During the first 13 months of the program (June 1, 2008 to June 30, 2009), Cary offered a $150 rebate per toilet for water customers who replaced toilets that use at least 3.5 gallons per flush (gpf) with WaterSense labeled high efficiency toilets that use 1.28 gpf in their homes.[9] Rebates were limited to three per residence and homeowners had to submit original receipt(s) for the HET toilets with purchase dates on or after June 3, 2008. During the second year of the program, the Town reduced the rebate amount to $100 for up to two toilets. Site visits were initially scheduled to ensure toilets had been installed, but after 100% compliance rates were observed, the Town simply recorded the installation date of each toilet for the remainder of the program.[10]

Cary budgeted an amount sufficient to replace 592 toilets in the first year and 790 toilets in the second year. In the first year, 305 households received rebates for 592 toilets and in the second year, 378 households received rebates for 603 toilets, indicating that the rebate funds were not fully exhausted in the second year.

*Household Water Use Data*

Actual water use data is obtained for each household participating in the first two years of the rebate program. Monthly billing data for all 683 households, covering 1,195 HET installations, were obtained directly from the water utility for the months January 1, 2007 through September 1, 2010. The utility also provided billing data for a matched set of "neighbors" for each rebate program participant over the same time period (Jan. 2007 - Sept. 2010). Ideally, matched households would be similar in terms of the number of people living in

[9] The rebate program also included businesses, however only two rebates were distributed to commercial customers which we do not include in our analysis. Furthermore, 10% of the rebates offered were reserved for customers who had newer 1.6gpf toilets. These households are also not part of our study.
[10] The installation date is self-reported by households on their rebate applications.

the house, the number of bathrooms, and their general outdoor and indoor water use habits. This type of information is not available and so the set of HET households are matched to control households who have similar property characteristics in terms of the size of their home and property. A household is considered a match for a rebate household if:

(1) the parcel lies within a 0.5 mile radius of the rebate house;

(2) the parcel is the exact same land class (i.e., single-family residential);

(3) the parcel's acreage is within 0.1 acres of the rebate home's acreage;

(4) the home has a square footage that is within 350 square feet of the rebate house; and

(5) the "matched neighbor" is not another HET house.

There were 25,100 parcels that fit the criteria above, or an average of 37 neighbors to each rebate household. The maximum number of matched neighbors to a single rebate household was 321 and the minimum was one household.

Figure 1 presents the mean monthly water consumption for rebate recipients and their matched neighbors over the 44-month study period. The apparent divergence in mean monthly water use of the rebate households from their matched neighbors after the rebate program begins is striking. Figure 1 also highlights the length of monthly data we have available pre- and post-program to help identify the effects of the HET program on monthly water use. Note also the peak in water consumption during summer 2007 (see Figure 1). This was due to a significant drought in the region. The water use of rebate households and matched neighbors increases dramatically during this drought period, but in a similar manner.

Table 1 presents the average monthly water consumption statistics for our sample of households. Over the entire sample period, the mean monthly water use was 4,506 gallons per month. Prior to the rebate program's implementation the mean use was 4,695 gallons per month and it was 4,385 gallons per month after the program's implementation, a difference of 310 gallons per month. Table 1 also reports the mean monthly water use for our sample excluding summer months. When the summer months are excluded, the mean monthly water use for the entire sample during the pre-rebate program months decreases by 394 gallons from 4,695 to 4,301 gallons per month. A similar pattern is present in the post-program months when summer water use is excluded.

Lastly, Table 1 reports the mean monthly water use by whether or not a household participated in the rebate program. The striking similarity of average water use of rebate households to non-rebate households prior to the implementation of the rebate program is apparent in these summary statistics. The mean pre-program monthly water use is 4,741 for rebate households (including summer months) and 4,695 for non-rebate households (difference = 46 gallons). The difference is also small (68 gallons) if the summer months are excluded.

*Survey of Rebate Program Participants*

Table 2 summarizes the installations by the rebate households. There was an average of 1.74 HET installations per household. Most households (49%) received a rebate for two HETs, while 38% of households received a rebate for only one HET. The remaining 13% received a rebate for three HET installations. Table 2 also indicates the distribution of HET installations across time. During the first year of the program (June 1, 2008 to July 1, 2009) most rebates were given out in the first six months. In the second year of the program, the rebates were spaced more evenly throughout the time frame. This unequal temporal distribution of rebates in the first year may reflect the fact that the program was more generous (both in terms of dollars per toilet and number of toilets) and funding actually ran out in that year. It may also suggest that households who would have replaced toilets prior to the rebate program waited until the rebate program was in place to take advantage of the subsidy. This is consistent with evidence of inter-temporal substitution of car purchases in response to tax rebates for hybrid vehicles (Sallee, 2011).

To understand how the rebate affected households' decisions to replace toilets, a survey was mailed to all 305 residential customers receiving rebates during the first year of the program. The surveys were mailed on June 17, 2010 and of the 305 surveys mailed, six were undeliverable due to moves with no forwarding addresses.[11] Of the 299 deliverable surveys, 245 were returned for a response rate of 80.3%. Of these 245 surveys, one was not usable because the ID number had been marked through and thus could not be matched back to utility records, leaving 244 usable surveys. These 244 survey respondents reported that they installed 527 HET toilets. Of the toilets installed, 523 received a rebate. Thus, our survey respondents cover 88% of the 592 toilets that received a rebate in first year of the program.

Table 3 summarizes the demographic and housing characteristics of the survey respondents. The rebate recipients are highly educated (88% have at least a college degree) and have household incomes well above the national averages (mean household income = $97,705). These statistics are, however, similar to the general demographics of Cary, which are provided in column (3) of Table 3 for reference. As compared to the general citizenry of Cary, rebate participants are somewhat older, more educated, and have fewer minorities represented. These differences are not surprising given rebate participants must be homeowners and the demographics reported for the Town of Cary reflect all adult citizens of the town.

[11] Following Dillman (1978), two weeks after the initial survey was mailed, a reminder post-card was mailed to those who had not yet returned the survey. Three weeks after the reminder post-card was mailed, a second blank survey with a reminder cover-letter was mailed to those who still had not returned the survey. The cover letter indicated that it was the last time they would be contacted by the researchers.

The survey also collected information on a few key features of the rebate participant's home. The average age of a home that received a rebate is older than for the general housing stock in Cary (26 years versus 18 years). Individuals who received a rebate also have lived in their home slightly longer than the average for the Town (14 years versus 11 years). Beginning in 1990 Cary housing codes required installation of 1.6 gpf toilets in all new housing and Cary experienced extraordinary growth in home starts during the 1990s and 2000s. Both of these suggest that rebate recipients will live in housing that is older than the average for Cary as a whole. The mean and median number of bathrooms per home is three, indicating that for a substantial portion of surveyed households (82%), the three rebates offered in the first year of the program could replace all toilets in the house. In the second year of the program, the Town reduced the number of rebates per household to two, which would cover all toilets in the home for only 17% of households (assuming the second year's program participants had home structures similar to the first year's participants).

The survey also asked rebate recipients a series of questions about the basis for their decision to replace *each* toilet, and thus, we can determine whether each rebate resulted in complete, partial, or no change in water consumption.[12] There are three ways the rebate program could influence a household's toilet replacement decision. First, the household may <u>not</u> have been planning to replace their old toilet, and the rebate program induced them to do so. In this instance, the water savings implied by the toilet replacement is attributable to the rebate. In the second case, the household may have been planning to replace their old toilet with a new, but not high-efficiency toilet and the rebate program induced them to move to a HET. For this group, the water savings that can be attributed to the rebate is roughly 0.32 gpf, which is the difference

[12] The portion of the survey containing these questions along with the algorithm mapping answers to these questions to the three categories of water consumption change attributable to the rebate (complete, partial, no change) can be found in Appendix A.

between the gpf of a new, but not efficient toilet (1.6 gpf) and a HET (1.28 gpf).[13] Lastly, there may have been households who were planning to replace their old toilet with a HET, regardless of the rebate program. In this case, the rebate was simply a windfall gain to the household and the municipality received no additional water savings as a result of the rebate expenditure.

Table 4 summarizes the responses. There were 240 households that provided complete information for 485 HET installations. Among these households, 80% knew about the rebate program prior to deciding to replace their old toilet and 83% replaced only their toilet (i.e., the replacement was not part of a larger renovation). At first blush, these two statistics might lead one to assume that most of the HET installations occurred as a result of the rebates. However, analysis of survey data on the motivation for replacing the first toilet indicate that only 33% of old toilets were replaced *because of* the rebate, and 47% of rebates were given to households that would have replaced their toilets with a HET *absent the rebate*. Lastly, 20% of the rebates went to households who had planned to replace their toilets with a new, but not high-efficiency toilet, but the rebate induced them to move to a HET.

The proportion of individuals that replace a toilet solely because of the rebate (33%) may seem lower than one might expect a-priori. There have been recent examinations of rebate programs in other markets, and in particular for hybrid vehicle adoption. Income tax, sales tax, and direct-cash rebates for hybrid vehicle purchases have been analyzed in the U.S. and Canada and results indicate that rebates induced as little as 6 to 32 percent of the purchases of hybrid vehicles (Chandra, et al., 2010; Beresteanu and Li, 2011, Ghallager and Muehlegger, 2011). However, comparing these two types of programs is difficult. A new car purchase is obviously a much larger proportion of household income, and the rebate on a new automobile is a much

[13] Beginning in 1991, all toilets had to use no more than 1.6 gpf, which remains the industry standard for new, non-efficient, toilets.

smaller proportion of the total cost (usually 10% or less). New high-efficiency toilets have come down in price over the years and the Town of Cary rebate ($100-$150) was sufficient to cover 100% of the purchase price if one chose a model at the lower-end of the price spectrum.

Anecdotal evidence also suggests that the relatively small proportion of households motivated to install a HET solely because of the rebate is likely reasonable. Inspection of retail offerings at the two national-chain home improvement stores located in, or very near, the Cary city limits indicates that over 85% of in-stock toilet models were labeled “watersense,” the US EPA’s rating that indicates a toilet is high-efficiency. Further, the retail price of HET and non-HET toilets overlap nearly completely.[14] The main exception is the highest-priced toilets (over $350) that were special-order only, in which only one of the six toilets was a HET. The lowest priced HET was approximately $90, and the majority of toilets (HET or not) were priced in the $100 to $250 range. Casual conversation with section managers at the stores also indicated that they knew the details of the rebate program and discussed the program with potential purchasers. Therefore, households replacing toilets for any reason were likely to choose a HET and get a rebate and it is not surprising that this constitutes a large percentage of total toilet replacements.

## 3. Estimation Strategy and Results

*Estimation Strategy*

There are two water savings estimates potentially of interest to policy makers. The first estimate of interest is the impact of HET *installation* on water use. There are engineering

[14] The authors surveyed home improvement stores in 2012. We recognize that this is four years after the first year of the rebate program, and the availability and cost structure of HETs relative to non-HET toilets may have changed. Unfortunately, we cannot reconstruct the distribution of retail toilets or their prices in summer/fall 2008 when the program first began. However, we do know that by the implementation of the HET rebate program there were HET models available for less than $150 since the Town received proof of purchase for HET models for which the rebate covered the entire purchase costs.

estimates of this parameter, but one might be concerned that actual water savings differ from expected water savings if the household uses the newer toilet differently. In particular, one may be concerned about so-called rebound effects, where the household increases water use because their appliance is more efficient. This has been shown to be a significant issue for energy-saving appliances (Greening et al. 2000; Davis 2008) and could be a concern for HETs although it is unlikely that a household will use a toilet more frequently simply because it is more efficient. A more likely avenue that newer toilets could be used differently is that if the newer HET removes waste less efficiently, there may be more flushes per visit. Alternatively, if only some toilets in a household are replaced, bathrooms may be used differently, with the household choosing the bathroom with the HET more frequently to increase water savings (or less frequently if the HET does not eliminate waste well). Overall, it is uncertain how much water savings there would be with an HET replacement for a variety of factors, and thus it is worth estimating the average effect of HET adoption/installation on water savings.

The second estimate policy makers could find of interest is the water savings that can be expected from subsidizing HET installation through rebates. This estimate provides information on how much *additional* water savings from HET installations occur when HETs subsidies are offered. In many ways this is the more interesting policy parameter because it directly connects the policy (subsidization) to the outcome (water savings).

In an ideal experiment for measuring water savings from HET *installation* (ideal experiment #1), households would be randomly assigned HET toilets and the resulting differences in mean water use between households assigned a HET and those that are not assigned a HET could reasonably be viewed as the average effect of adoption. Similarly, an ideal experiment for measuring water savings from HET *subsidization* (ideal experiment #2) would randomly assign households to be eligible for a HET subsidy. Some of the households eligible for the subsidy would choose to take advantage of it and install a HET, and some would not. In addition, some households that are not offered a subsidy might choose to install a HET anyway. In this experiment, the resulting differences in HET installation rates and water use between the households that were eligible for the subsidy and the households that were not eligible for the subsidy could be reasonably viewed as an intent-to-treat (ITT) estimate of the effect of subsidization.

To approximate ideal experiment #1 with observational data, a difference-in-differences estimator can be constructed that compares water use pre- and post-HET installation among those installing a HET or not:[15]

$$\begin{aligned} DID^{ATE} = &\left\{ E\left[W_1 \mid T=1\right] - E\left[W_1 \mid T=0,\right]\right\} - \\ &\left\{ E\left[W_0 \mid T=1\right] - E\left[W_0 \mid T=0\right]\right\}, \end{aligned} \qquad (1)$$

where $W_0$ and $W_1$ are the water use of a household pre- and post-installation, respectively, and T is a time-invariant indicator variable that takes a value of 1 if the household will eventually install at HET and 0 if the households never installs a HET. While one may be concerned about selection effects – differences among households that choose to install a HET and households that do not that are also correlated with water use (e.g., size of the household, baseline water use, income, etc) – if these differences are time invariant, then the DID estimator in (1) is unbiased. We label the estimator $DID^{ATE}$ because it approximates the average treatment effect where treatment is defined as HET installation. In other words, $DID^{ATE}$ provides an estimate of the water savings associated with HET *installation*.

[15] In all equations in this section, we assume, without loss of generality, that "treatment" happens at one time thereby creating distinct pre- and post-treatment periods and that no households have a HET prior to the "treatment."

To approximate ideal experiment #2 with observational data, one can compare HET adoption in a treatment group eligible for a subsidy with a control group that represents adoption in absence of having a subsidy available (i.e., representing the "natural" rate of adoption). More formally, a difference-in-difference estimator in this case has the following form:

$$DID^{ITT} = \{E[W_1 \mid A=1, H \in \{0,1\}] - E[W_1 \mid A=0, H \in \{0,1\}]\} - \{E[W_0 \mid A=1, H=0] - E[W_0 \mid A=0, H=0]\}, \quad (2)$$

where $W_0$ and $W_1$ are as previously defined, A is a time-invariant indicator that takes a value of 1 if the subsidy is available to the household and 0 if not, and H is equal to one if a HET is installed and is equal to zero if a HET is not installed. We label this estimator $DID^{ITT}$ because it is similar to the "intent-to-treat" estimator where having a subsidy available is equivalent to being assigned to the treatment group and HET installation is equivalent to treatment uptake (see Angrist and Pischke 2008).

It is not possible to directly estimate either equation (1) or (2) for the Cary rebate program. We cannot estimate equation (1) because we do not have data on HET adoption among households who did not apply for a subsidy, and hence cannot be sure that H=0 for all households in our control group. Similarly, we cannot estimate equation (2) because the subsidy is available to all households in the sample and again we cannot be sure the control group represents the rate of HET adoption absent the subsidy. Instead, the following DID estimator is constructed with the observational data at hand:

$$DID^{HET} = \{E[W_1 \mid A=1, S=1, H=1] - E[W_1 \mid A=1, S=0, H \in \{0,1\}]\} - \{E[W_0 \mid A=1, S=1, H=0] - E[W_0 \mid A=1, S=0, H=0]\}, \quad (3)$$

where S is a time-invariant indicator that takes a value of 1 if the household receives a subsidy through the rebate program and 0 if not, and all other variables are defined as before. Note, equation (3) makes explicit that the subsidy is available to all households, but not all households may take advantage of it even if they choose to replace a toilet with an HET.

The estimated $\text{DID}^{\text{HET}}$ always lies between the two policy parameters of potential interest, i.e., $DID^{ITT} \le DID^{HET} \le DID^{ATE}$. It is easy to see that $\text{DID}^{\text{HET}}$ is no greater than the $\text{DID}^{\text{ATE}}$ because the $\text{DID}^{\text{ATE}}$ includes no installation of HETs in the control group, while installations in the control group are possible for $\text{DID}^{\text{HET}}$. To the extent that households in our control group install a HET, but do not apply for a subsidy, $\text{DID}^{\text{HET}}$ will be lower than the true savings from HET installation as given by $\text{DID}^{\text{ATE}}$. It is also the case that $\text{DID}^{\text{HET}}$ always lies above $\text{DID}^{\text{ITT}}$. This is because the experimental design giving rise to $\text{DID}^{\text{HET}}$ implies that all households in the treatment group install a HET, while in the experimental design of $\text{DID}^{\text{ITT}}$ some treated households for which the subsidy is available may choose not to install a HET.

Given that the natural rate of toilet replacement is expected to be quite low[16] and the point-of-sale advertising of the rebate program, we find it likely that $\text{DID}^{\text{HET}}$ lies very close to $\text{DID}^{\text{ATE}}$. In other words, we expect that the vast majority of households that chose to install a HET knew about and applied for the subsidy, and therefore, households in the control group are non-adopters.[17] This implies that the estimated $\text{DID}^{\text{HET}}$ is a close approximation of $\text{DID}^{\text{ATE}}$. To get an approximation of the $\text{DID}^{\text{ITT}}$, the $\text{DID}^{\text{HET}}$ must be adjusted to reflect the fact that some households would have installed a HET in absence of the subsidy.

The survey data of rebate recipients provides the required information to adjust $\text{DID}^{\text{HET}}$ to approximate $\text{DID}^{\text{ITT}}$. Recall, the survey asked households to report their motivation for

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[16] Toilets have a life expectancy of 50 years or longer, although parts may wear out faster.

[17] Additional anecdotal evidence suggests this to be the case. The Town of Cary reports that it receives approximately 30 toilets per month at its disposal facility that accepts toilets. Subsidy recipients alone average 27 toilet disposals a month, assuming all toilets replaced are sent to the town's reclamation facility. In addition, the largest home improvement store in Cary indicated that it would be reasonable to assume that toilet sales were not greater than 30 per month in the store (exact sales data was not be shared with the researchers). As such, we find it highly unlikely that a large enough portion of non-subsidy households are installing HET toilets such that $\text{DID}^{\text{HET}}$ is significantly biased away from $\text{DID}^{\text{ATE}}$.

replacing their old toilets (see discussion in section 2). These survey responses are used to adjust the estimated $DID^{HET}$ and compute $DID^{HET\text{-}A}$ that is an approximation of $DID^{ITT}$:

$$DID^{HET-A} = \rho_1 DID^{HET} + 0.20\rho_2 DID^{HET}, \qquad (4)$$

where $\rho_1$ is the proportion of households in the survey that self-report that they replaced their old toilet solely because of the subsidy and $\rho_2$ is the proportion of households planning to replace their toilet with a new, but not high-efficiency toilet and chose a HET because of the subsidy. The water savings attributable to the subsidy program for this latter group of households is 20% of the $DID^{HET}$ estimate since the subsidy resulted only in a change from a new 1.6gpf toilet to a 1.28 gpf toilet (0.2=[1.6-1.28]/1.6). Lastly, the proportion of households that indicate that they intended to replace their toilet with a HET regardless of the rebate do not appear in equation (4) because the water savings attributable to the rebate program for this group is zero. The survey data provides $\rho_1$ and $\rho_2$ directly. As indicated in Table 4, $\rho_1 = 0.33$ and $\rho_2 = 0.20$.[18]

Our estimation strategy proceeds in two steps. The first is to compute equation (3) directly using the mean water consumption data as presented in Table 1. We then refine these estimates to provide more detail on the impacts of each toilet that received a subsidy by estimating the following:

$$\begin{aligned} Water_{it} &= b_1 HET1_i + b_2 HET2_i + b_3 HET3_i + g_t + \\ & d_1 HET1_i * D1_{it} + d_2 HET2_i * D2_{it} + d_3 HET3_i * D3_{it} + e_{it} \end{aligned} \qquad (5)$$

where *Water*, is the water use (in gallons) of household *i* in time *t*; *HET1*, *HET2*, and *HET3*, are dummy variables equal to one if the household installed and received a rebate for one, two or three HETs, respectively; $\gamma_t$ are month-year dummy variables. The final three terms are

[18] As a referee pointed out, the survey may elicit strategic behavior from respondents given the close connection between the survey and the utility that runs the rebate program. We assume that given the positive comments about the rebate program received in the survey, that any strategy would be to overstate the importance of the rebate in the decision-making process in order to continue the program and/or encourage similar programs. To the extent this is the case, our estimates of $\rho_1$ and $\rho_2$ are overstated.

constructed by interacting the household HET type (1, 2, or 3 toilets installed) with a month-specific treatment indicator that takes a value of 1 after the household installs their first, second, or third HET, respectively.  For example, if household *i* installs their first HET toilet in month 22, their second HET toilet in month 24, and their third HET toilet in month 26, $D1_{it}$ would equal 1 for months 22 and 23, $D2_{it}$ would equal 1 for months 24 and 25 and $D3_{it}$ would equal 1 for months greater than or equal to 26. For households that install more than one HET in the same month, the dummy variable corresponding to the total number of HETs installed in that month equals 1 and the other dummy variables equal zero.  For example, if a household installed two HETs in June, then D2 would equal 1 in June (and all subsequent months) but D1 would still be set to zero. In practice, nearly all households installed their HETs on the same date (only 13 of 683 households installed HETs on two distinct dates), and thus the coefficients $\delta_1$, $\delta_2$, and $\delta_3$ are difference-in-differences estimates for the total water savings from installation of 1, 2, or 3 HET toilets, respectively, relative to a household that has installed no HET toilets.

We also estimate a more general version of the equation that includes household level fixed-effects, $\phi_i$.  In this specification, the coefficients on the HET dummy variables $(\beta_1, \beta_2, \beta_3)$ can no longer be identified and the equation estimated is:

$$Water_{it} = \gamma_t + \delta_1 HET1_i * D1_{it} + \delta_2 HET2_i * D2_{it} + \delta_3 HET3_i * D3_{it} + \phi_i + \varepsilon_{it} \qquad (6)$$

Finally, we relax our assumptions about the nature of the exogenous time trends.  Equations (5) and (6) impose common (but non-linear) time trends across all households.  We cannot include household-specific time trends in equations (5) or (6), but we can more flexibly control for time trends among similar groups of households.  Each control observation is assigned to at least one treatment observation which we define as a "rebate group" (i.e., the set of homes assigned to a particular household that received a rebate) and we can include separate time trends by rebate group which results in the following specification:

$$Water_{it} = RG_i * g_t + d_1 HET1_i * D1_{it} + d_2 HET2_i * D2_{it} + d_3 HET3_i * D3_{it} + f_i + e_{it}, \quad (7)$$

where $RG_i$ is the rebate group associated with household i.

Equations (5) - (7) are estimated using two different assumptions on the structure of the error term. The first is to cluster at the household level, allowing for serial correlation among observations from the same household over time, but assuming independence of observations across households. However, given that the matched sample was constructed by neighborhood, it is possible that observations, while independent across neighborhoods, may not be independent within neighborhoods. To allow for this possibility, models are also be estimated with standard errors clustered by rebate group. Results with standard errors clustered by rebate group are qualitatively identical to those clustering by household (all significance levels stay identical across models) and so we only report models with household-level clustering.[19]

*Results*

The simple DID estimate of water savings can be calculated directly from the data presented in Table 1. Differences in water use post-program less pre-program is -928 gallons for households receiving a HET subsidy (-710 gallons excluding summer months), while the same temporal difference for control households is only -308 gallons (-111 gallons excluding summer months). The simple DID estimate of the water savings among HET subsidy households is thus -620 gallons per month per household or -599 gallons per month per household if summer months are excluded. The average number of toilets installed during the study period is 1.74 per

[19] Results with standard errors clustered by rebate group are available from the authors upon request.

household, and thus the average water savings per toilet is estimated to be 356 gallons per month (or 344 per month if summer months are excluded).

The simple DID estimate is refined by estimating equations (5) through (7). The model in equation (5) is estimated on a panel of 683 rebate households, 112,191 matched observations (including duplicates for parcels that served as a match for more than one rebate household), and 44 months of billing data for a total of 4,579,439 observations. The fixed-effects models in (6) and (7) are estimated without duplicate control households and the number of observations is reduced to 1,038,615. [20]

The results for all DID estimations are presented in Table 5. Results from estimation of equation (5) is in the first column and indicates that installation of a single HET toilet reduces water consumption by 354 gallons per month relative to no toilets. Installation of two and three HET toilets reduces water consumption by 767 and 913 gallons per month relative to installing no HET toilets, respectively. These estimates are statistically significant at the 5% level or better. The coefficients taken together imply that the average water savings for the sample of households that received a subsidy is 362 gallons per month per toilet, with a 95% confidence interval of 184 to 540 gallons per month.

It is interesting to note that the DID estimate from the model in equation (5) is nearly identical to the simple DID estimate of average savings and to an engineering estimate of water savings that can be computed using the survey data. An engineering estimate of water savings is computed by multiplying the gallons per flush that are saved by installing a HET, $\Delta$gpf, by the expected number of flushes per month. The survey data on the number of individuals and bathrooms in each household is used to compute the expected number of flushes per toilet. We assume each toilet in the house is used equally and that each person in a household flushes a

[20] Not all matched households had complete billing data for all 44 months, and so the panel is unbalanced.

toilet at home an average of 5.1 times per day as reported by Meyer, et al. 1999. Thus, the per month engineering savings are computed as $\Delta$gpf*(total flushes by household / total toilets in household)*30 days. On an engineering basis alone, installation of an HET should result in an average reduction of water use by approximately 366 gallons per month, assuming no behavioral responses to HET installations.[21]

The results for the models given by equations (6) and (7) that incorporates household-level fixed-effects are presented in columns (2) and (3) of Table 5. The average water savings per month, per toilet, is somewhat smaller than what is estimated by the model without household-level fixed effects (see column 1). Columns (2) and (3) indicate average water savings of 298-301 gallons per month, per toilet. While this is 17% smaller than the estimates presented in column (1), all 95% confidence intervals overlap and thus these are not significantly smaller estimates of per-month water savings.

As indicated in the previous section, we believe the DID estimates presented in Table 5 provide a close approximation of $DID^{ATE}$, or the water savings associated with HET *installation*. The estimates presented in columns (2) and (3) are our preferred estimates because inclusion of the household fixed effects provides the most complete control for unobservable time-invariant heterogeneity. Given this, equation (4) is now used to compute the $DID^{HET\text{-}A}$ and provide an estimate of $DID^{ITT}$. The data suggest that $DID^{ITT}$, or the additional water savings induced by the rebate program, is 111 gallons per month (with a 95% confidence interval of 68-164), or 37% of the total water savings associated with HET installations.

[21] The similarity between the DID estimate and the engineering estimate is suggestive that there is little rebound effect associated with HET installation. HETs were notorious for needing "double-flushing" to remove waste properly when first marketed. However, our results suggest this is not likely an issue with current models even despite the recent ratings by Consumer Reports that indicated "Our latest tests of 25 toilets show that the best performers still use the standard 1.6 gallons of water per flush." (August 2009 issue of *Consumer Reports*®, "Toilets: We found low-flow toilets that really work," available through subscription to consumerreports.org.) It is also the case that 82% of our survey respondents ranked their satisfaction with their new HET toilet(s) an 8 or a 9, on a 1-9 scale with 9 indicating "very satisfied."

*Robustness Analysis*

The validity of the DID estimates, and our conclusions about average water savings, hinges on the assumption that in the absence of the treatment trends in water use between HET adoptions/rebate households and non-rebate households would have been parallel. We test the validity of this identifying assumption using data from the pre-treatment period. Before households adopted a HET and received a rebate, there should not be any statistically significant differences in water use trends. In order to test for common trend prior to the start of the HET rebate program, water consumption data prior to the start the HET rebate program from January through December 2007 is used to estimate the following DID model:

$$Water_{im} = B_1 HET1_i + B_2 HET2_i + B_3 HET3_i + \gamma_m +$$

$$\delta_1 HET1_i * D1_{im^T} + \delta_2 HET2_i * D2_{im^{+1}} + \delta_3 HET3_i * D3_{im^{+1}} + \varepsilon_{it} \quad (8)$$

where all variables are as defined for equation (3), but we now regress water use of household i in month m ($m \in [1,12]$) on pseudo-treatment indicators, $D1_{im^T}, D2_{im^T},$ or $D3_{im^T},$ that are equal to one in the month that a household installs their first, second or third HET, respectively, in *future* years and every month thereafter. For instance, if a household installs only one HET in August 2009, the pseudo-treatment indictor $D1_{im^T}$ is equal to one for months 9 through 12 when estimating equation (8). Results from this model can be found in the first column of Table 6. The DID coefficients are not statistically significant in the pretreatment period, indicating that prior to subsidized HET installation there is no difference in trends in water use among the treatment and control households. This bolsters our confidence in the validity of the DID approach.

A second concern is about the quality of control matches. While matches on location and land class were exact, matches on acreage and square footage were approximate. Because the calipers used to match on acreage and square footage were tight (0.1 acres and 350 square feet, respectively), the means of these two variables for treatment and control households are not statistically different from one another. However, as Iacus, King, and Porro (2011) note, differences in the *distribution* of matching covariates can lead to bias in standard treatment effects estimators even when the means are the same. Iacus, King, and Porro (2011) suggest a quartile-quartile plot (qqplot) to evaluate differences in the distribution of control variables. We provide a qqpolt of acreage and square footage for the whole sample in panels A and B in Figure 2. The 45 degree line represents equality in the quartiles and for the whole sample there is evidence of a difference in distribution particularly at the higher end of the distribution (greater acreage or greater square footage). The reason for this difference in distribution is that there are more control matches for households that are smaller and have less acreage. For example, a large lot in Cary is very rare and may only have 1 or 2 matches within 0.5 miles. A smaller household on a smaller lot may have 10 matches. Therefore, smaller homes on smaller lots represent a larger portion of the control distribution relative to the treatment distribution.

To determine if the differences in distribution affects the estimates we randomly select four matches for all treatment households. If a household has fewer than four matches, all matches are used. Because the number of matches is more equal across all acreage and square footage levels the distributions are more similar. This is reflected in panels C and D of Figure 2. We estimate the baseline and fixed effects models (equations 5 and 6) on the randomly selected sample. The results are presented in columns 2 and 3 of Table 6. The results on the restricted sample are very similar to results on the full sample, and indicate that the results presented in

Table 5 do not suffer from bias induced by differences in the distribution of the covariates used to match treatment and control households.

## 4. Cost-effectiveness of the Rebate Program

The prior section demonstrates that the HET *installations* can result in significant water savings: an average of 300 gallons per month per toilet, or approximately 7% of estimated indoor water use for our sample of homes.[22] However, these positive results do not necessarily mean that the *rebate program* was good policy. The cost-effectiveness of rebate programs hinges on the process by which households select into the rebate program. If all households who receive a rebate would have installed HET toilets in the absence of the rebate, then there are no additional water savings and the rebate acts as a simple transfer payment. In the previous section we also demonstrate that the additional water savings induced by the rebate program is somewhat limited: 111 gallons per month or only 37% of the total water savings associated with HET installations.

This section explores the cost-effectiveness of the rebate program in light of its limited additionality. Rebate programs offered by regulated utilities can be viewed as transfer programs from one segment of rate-payers to another. However, water utilities are often mandated by state or local jurisdictions to implement conservation programs and must allocate funds from existing revenues for these purposes. Thus, from the perspective of a water utility manager, the cost-per-gallon-reduced by the rebate program is an important statistic to understand and compare to alterative actions that can be undertaken. To determine the cost-effectiveness of the HET rebate

[22] The estimate of indoor water use is 4,300 gallons per month, which is the pre-rebate program average water use excluding the summer months of May-September 2007.

program, an annualized cost-per-gallon saved is computed and compared to other actions the Town might have considered.

To determine the cost-effectiveness of the rebate program, we must consider what would have happened to an older toilet had the rebate program not been in effect. Water savings accrue to the water utility over time, although the rebate expenditure is a one-time, up-front payment. To determine an annual cost-effectiveness measure, we have to know the period over which the water savings occur due to the rebate. One might assume that the conservation associated with an HET installation lasts for the life of the toilet. However, this assumes that the old toilet would never have been replaced at some future point in time. This seems unrealistic. We thus compute the cost-effectiveness under a variety of assumptions about how long it would have taken the old toilet to be replaced had the rebate program not existed. Specifically, we assume 5, 10, 15 and 30 years.

Because we only have survey data available for the first year of the program to determine the household's motivation for replacing old toilets, cost effectiveness measures are only calculated for that year.[23] In the first year of the rebate program, the Town of Cary spent $150 per HET rebate or $88,800 for the 592 HET replacements. To convert the Town's rebate expenditures from an up-front payment to an equivalent annuity payment, we use a 5% interest rate.[24] The cost-effectiveness of the rebate program is then computed as the annual annuity cost

[23] We could estimate cost-effectiveness for year two assuming that the lower $100 rebate would result in the same proportion of *Group 1*, *Group 2*, and *Group 3* households as described in Section 2 (recall, the survey was conducted only for year 1 participants who received $150 per toilet). While this could be the case, we find it more likely that when the rebate is smaller, it is less likely that it will fully incentivize a toilet replacement that would not have occurred otherwise.

[24] The Town of Cary typically uses 5% as its cost of capital when analyzing potential projects.

divided by the annual gallons saved. The estimated average annual gallons saved as a result of the HET rebate program is 788,544 gallons.[25]

Table 7 presents the cost-effectiveness estimates for the rebate program and indicates a range of $7.33 to $26.01 per 1,000 gallons conserved, depending the assumed life of the old toilet in absence of the rebate program. While we have no evidence to draw upon, we consider 10-15 years a reasonable mid-point estimate. With this in mind, our comparative discussion on cost-effectiveness focuses on the estimates of $10.85 to $14.58 per 1,000 gallons.

For comparison, the Town of Cary suggests that the average costs of producing 1,000 gallons of potable water that flows from Cary to a household is best represented by their Tier 2 residential potable rate of $4.08 per 1,000 gallons. The average cost of collecting, treating and disposing 1,000 gallons that flows back to a wastewater treatment plant is represented by their sewer rate of $7.08 per 1,000 gallons. A "full circuit" for water that is used by a toilet is thus estimated to cost $11.16 per 1,000 gallons, including all annual costs to operate the utility. Thus, from the utility's standpoint, the cost of reducing household use by 1,000 gallons through the rebate program appears to be competitive with the cost of supplying that same 1,000 gallons to the household. Alternatively, one can consider the opportunity cost to the utility when capacity must be expanded in order to meet demand. The Town of Cary currently estimates capacity expansion would cost approximately $7 per 1,000 gallons. Here, the rebate program fares worse and appears not to be a competitive alternative to capacity expansion (except with a 30 year replacement horizon).

A larger question is whether the rebate program is cost-effective relative to other tools the utility may undertake to manage residential indoor water demand. This question is relevant if it

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[25] Average annual water savings resulting from the rebate program are the average monthly savings as estimated by the $DID^{ITT}$, or 1,332 gallons per year (=111 gallons per month x 12), multiplied by the number of toilets replaced in the first year of the rebate program (592 toilets).

is the case that the utility has a mandate to undertake demand-side management programs and is choosing among programs maximize water saved per dollar spent. Other than price changes, the tool-kit for managing indoor water use is limited to subsidy/rebate programs for retrofits and educational campaigns.

As indicated earlier, we are aware of no past analysis of rebate program cost-effectiveness for any efficient appliance. However, there is evidence on cost-effectiveness of information campaigns to reduce water consumption. Ferraro and Price (2011) conduct a large-scale field experiment in Atlanta, Georgia and find that some types of information messages reduced average household water consumption by nearly 5% in the period just after the information is received.[26] Given the relatively low costs of printing and mailing the information, they estimate a cost per 1,000 gallons reduced to be under 60 cents – more than an order of magnitude more cost-effective than the HET rebate program. However, it is important to note that the impacts of the information campaign are shown to wane over time (Ferraro et al., 2011) while HET replacement affords permanent water conservation. We have no evidence available on what types of information must be given, and for how long, to result in consistent, permanent reductions in water consumption (see also Alcott, 2011, for an analysis of information campaigns in electricity consumption). As noted in Ferraro and Price (2011), future research could focus on

[26] Ferraro and Price (2011) conduct three treatments that vary information content. The first treatment included a "top ten tips" for reducing water consumption message that is commonly used in the industry; the second included the top-ten tips plus appeals to the public good that we must all do our part to conserve water; and the third included the first two information messages plus a social comparison. In the social comparison, households were told their rank in water consumption relative to the rest of the county's residential water users. Results indicated that water consumption in the months immediately following the information campaign did not change for households receiving the top-ten-tips message only, was modestly reduced for households receiving the appeal to the public good treatment, and 4.8% less in the social comparison treatment. Ferraro and Price note that the effects in the social comparison treatment were larger in the first month after the message was received, and waned by the end of the summer. Further, Ferraro et al. (2011) report that across years, there were no effects of the appeals to the public good treatment in the following year, and the effects of the social comparison information had waned to just over 1% two summers later.

the degree to which information campaigns can be designed that result in retrofits that can afford more permanent consumption reductions.

## 5. Conclusions

This research employs a unique data set on participants in a high-efficiency toilet rebate program and comparable households that did not participate to estimate the additionality and cost-effectiveness of the program. The data set combines surveys of participating households with over one-million observations on monthly water use from January 1997 to July 2010 for both participants and non-participants. The program studied here mimics the key features of most rebate programs targeting household retrofits of water or energy efficient appliances – namely, the program is available to all qualifying households in a utility service area. Given this feature, estimating the water savings that is *directly attributable* to the rebate program is not possible with water use data alone. To estimate the additionality of the rebate program a survey is conducted that provides critical information on the motivation of each household for purchasing and installing a high efficiency toilet.

On average for our sample, replacing a pre-1991 toilet with a HET reduces household water consumption by 301 gallons per month, or approximately 7% of monthly household water use. This estimate is quite similar to an engineering estimate of water savings that would result from replacement of the old toilets in our sample with HETs. While the *installation* of a HET appears to be an effective means for reducing household water consumption, the *rebate program* is a much less effective means for achieving household reductions in water consumption. Our results suggest that only 37% of the water savings associated with HET installation can be directly attributed to the rebate program. In other words, 63% of the water savings would have occurred even in absence of the rebate program. The reason for this is that the rebate induced very few households to replace a toilet that they weren't already planning on replacing. As such, the additionality of the rebate program is limited, and the cost-effectiveness is questionable relative to other uses of the utility's funds.

One policy implication from this analysis is that utilities may expect to get larger water reductions from a fixed subsidy budget by targeting households that would not otherwise replace their toilets. To examine this potential avenue, we compared the demographic, housing, and attitude data of rebate recipients who indicated that they would not have replaced their toilets without the rebate to those who indicated they would have replaced their toilets without the rebate. Unfortunately, there were no significant differences among their observable characteristics of these two groups.[27] If our results are robust to other study areas, it would be difficult for a utility to target information or rebates to increase the program's additionality.

A more promising approach for utilities may be to focus subsidy efforts away from voluntary household opt-in programs and towards institutional customers such as apartment complexes built prior to 1991. Our results strongly suggest that installation of a HET results in a reasonably secure return in terms of water savings – approximately 300 gallons per month, per residential toilet. We find it likely that toilets in renter-occupied housing are less likely to be replaced for cosmetic reasons, and housing built during the twenty-year period of 1970 to 1990 would have 3.5 gpf toilets (or higher) installed with remaining life expectancies of at least 10-15 years today. Revisiting our cost-effectiveness calculations in Section 4, if a utility were to purchase HETs directly for apartments (at $150 each), and they were installed, the utility could

[27] The only statistically significant difference among the groups was that households that were induced to move from a new toilet to a new HET had more individuals per household on average (2.92) as compared to households which already planned to replace their toilets with an HET even without the rebate (2.49).

achieve water reductions for as little as $4.00 to $5.38 per 1,000 gallons when all 300 gallons per month are attributable to the $150 expenditure.

In sum, many utilities (both water and electricity) have implemented demand side management programs, but it is rare to be guaranteed a specific reduction in water or energy use. Appliances such as low-flow shower heads, lower energy light bulbs and other energy efficiency appliances have all been associated with significant rebound effects (Greening et. al 2000; Davis 2008). High-efficiency toilets appears to be a better bet among demand side management options which may make it an attractive option for utilities facing water supply constraints. However, voluntary opt-in rebate programs for household retrofits may result in little additional water savings over what would naturally occur otherwise.

An alternative way to increase the cost-effectiveness of rebate program is to reduce the up-front cost of the rebate – i.e., to lower the rebate amount. To do so, however, may shift the incentives of the customers and result in fewer rebates being given to households that would not have replaced their toilets otherwise. Unfortunately, with the data we have available, we cannot shed light on how the incentives of households would change in response to changing rebate levels. This is an important avenue for future research, and in many ways high-efficiency toilet rebates are an ideal market to consider for these purposes. First, toilets are the largest source of indoor residential water use and therefore understanding how rebate programs affect incentives for retrofitting these appliances has significant implications for efficient water conservation policies. Second, rebates typically vary from $50 to $150 per toilet and can cover a substantial portion of the purchase price (over 100% for some models) or as little as 10% for the highest end models. Further, substitute new toilets that are not high-efficiency have similar price ranges. As such, this market is ideal for exploring the incentives of consumers to rebate amounts relative to appliance prices and relative to substitute non-efficient appliance prices.

**Table 1. Average monthly water consumption.**

| | Monthly Water Use | |
|---|---|---|
| | Mean | Standard Deviation |
| *Full Sample (N=25,783)* | | |
| January 2007 to July 2010 | 4,506 | 3,014 |
| Pre-program[a] | 4,695 | 3,206 |
| Pre-program, excluding May-October 2007 | 4,301 | 2,649 |
| Post-program[b] | 4,385 | 2,877 |
| Post-program, excluding May-October in each year | 4,189 | 2,574 |
| *Rebate Recipients Only (N=683)* | | |
| January 2007 to July 2010 | 4,332 | 2,985 |
| Pre-program[a] | 4,741 | 3,328 |
| Pre-program, excluding May-October 2007 | 4,234 | 2,470 |
| Post-program[b] | 3,813 | 2,676 |
| Post-program, excluding May-October in each year | 3,524 | 2,068 |
| *Non-rebate households (N=25,100)* | | |
| January 2007 to July 2010 | 4,507 | 3,014 |
| Pre-program[a] | 4,695 | 3,206 |
| Pre-program, excluding May-October 2007 | 4,302 | 2,651 |
| Post-program[b] | 4,387 | 2,878 |
| Post-program, excluding May-October in each year | 4,191 | 2,576 |

[a] Pre-program includes January 2007 through May 31, 2008.
[b] Post-program includes July 2008 through July 2010.

**Table 2. HET Installation Summary Statistics (N=683 households).**

| | |
|---|---|
| *Installations by Households* <br> *Standard deviations in parentheses* | |
| Total HET installations. | 1,195 |
| Mean number of HETs installed by household | 1.74<br>(0.67) |
| Households that received a rebate for 1 HET. | 261<br>(38%) |
| Households that received a rebate for 2 HETs. | 332<br>(49%) |
| Households that received a rebate for 3 HETs. | 90<br>(13%) |
| *HET Installations Over Time* <br> *Percentages of total in parentheses* | |
| HET installations between June 1 and December 30, 2008 | 474<br>(40%) |
| HET installations between January 1 and June 30, 2009 | 83<br>(7%) |
| HET installations between July 1 and December, 2009 | 259<br>(22%) |
| HET installations between January 1 and August 31, 2010 | 379<br>(32%) |

**Table 3. Select demographics for HET rebate program participants.**

| | (1) | (2) | (3) |
|---|---|---|---|
| | *No. of Survey Responses* | *HET Rebate Participants* | *Town of Cary*[a] |
| Mean Household Income (std. deviation) | 207 | \$97,705 (\$44,196) | \$83,750 |
| Mean Age of Survey Respondent (std. deviation) | 241 | 55.2 (13.5) | 44.4 |
| Mean No. People in Household (std. deviation) | 241 | 2.7 (1.2) | 2.9[b] |
| *Education*[c] | | | |
| High School or Less | 239 | 2.5% | 10.6% |
| Some College | 239 | 9.2% | 22.1% |
| College | 239 | 42.7% | 36.9% |
| MA | 239 | 34.7% | 23.6% |
| Ph.D. | 239 | 10.9% | 6.8% |
| *Race/Ethnicity of Survey Respondent* | | | |
| White | 232 | 90.1% | 83.2% |
| Asian | 232 | 3.4% | 5.6% |
| African American | 232 | 2.6% | 4.1% |
| Hispanic or Latino | 232 | 0.9% | 3.1% |
| Other | 232 | 3.0% | 4.1% |
| *Dwelling Characteristics* | | | |
| Mean Age of Home (std. deviation) | 238 | 26.1 (11.4) | 18.4[b] |
| Mean Number of Bathrooms (std. deviation) | 239 | 3.1 (0.8) | n/a |
| Mean Years Lived in Home (std. deviation) | 239 | 14 (10.4) | 10.6[b] |

[a] Information on Town of Cary demographics is obtained from the Town's 2010 Biennial Citizen Survey, a phone interview of 401residents over the age of 18 in January/February 2010. The survey results are available at: http://www.townofcary.org/Departments/Administration/pio/Surveys_and_Research/2010survey.htm, last accessed October 1, 2011. Standard deviations are not available.
[b] Statistic computed from the U.S. Census Bureau Fact Sheet for the Town of Cary, 2005-2009, with data provided by the American Community Survey, available at: http://factfinder.census.gov/home/saff/main.html?_lang=en
c Education is the highest level achieved by any member in the survey respondent's household.

**Table 4. Summary Statistics for HET Installations and Rebate Incentives.**

| *HET Installation Summary (N=240 Households, all HETs included)* | | |
|---|---|---|
| Mean number of HETs installed by survey household. | 2.2 | |
| Mean satisfaction with HET performance (on a scale of 1-9, with 9 indicating "very satisfied" and 1 indicating "not at all satisfied). | 8.2 | |
| Household knew about rebate program prior to deciding to replace the toilet. | 192/240 | (80%) |
| Replacing the toilet was part of a larger renovation. | 41/240 | (17%) |
| Percentage of HETs installed by the homeowner rather than paying a plumber or installing as part of a larger renovation.[a] | 50.5% | |
| *Motivation for Replacing Toilet*[b] | *# Toilets (N=226)* | |
| Household was not planning to replace old toilet, rebate program fully induced them to do so. | 161 | (33%) |
| Household was planning to replace old toilet with 1.6 gpf, rebate program induced them to choose HET. | 98 | (20%) |
| Household was planning to replace old toilet with an HET even without rebate. | 226 | (47%) |

[a] If more than one HET was installed in a household, some may have been installed professionally and others by the homeowner. Respondents were asked to indicate how each toilet was installed separately.

[b] There were survey responses for 523 households that received a subsidy for at least one toilet. However, of these, 22 respondents (24 HET installation) left the questions blank that would allow us to categorize how the rebate incentivized them, and another 18 households (34 HET installations) provided inconsistent answers and could not be categorized. Thus, the percentages of respondents in each category for "Motivation for Replacing Toilet" are computed with a base of 485 toilets.

**Table 5. Difference-in-Differences model results.**[a]

| Model: | (1) **Baseline Model** | (2) **Household (Meter) Fixed Effects** | (3) **Household (Meter) Fixed Effects with HET-group-specific time trends** |
|---|---|---|---|
| Constant | 4,513.2*** | 4,519.5*** | 4,584.1*** |
| | (22.8) | (14.6) | (32.9) |
| HET1 (one subsidy) | -69.9 | | |
| | (131.8) | | |
| HET2 (two subsidies) | -0.1 | | |
| | (110.1) | | |
| HET3 (three subsidies) | 316.3 | | |
| | (262.1) | | |
| HET1 * Post-installation | -354.3** | -392.0*** | -387.4*** |
| | (141.6) | (96.3) | (96.3) |
| HET2 * Post-installation | -767.5*** | -451.4*** | -448.4*** |
| | (116.7) | (64.9) | (65.0) |
| HET3 * Post-installation | -913.1*** | -962.9*** | -950.7*** |
| | (190.7) | (157.3) | (157.4) |
| Observations | 4,579,415 | 1,038,615 | 1,038,615 |
| R-squared | 0.02 | 0.05 | 0.05 |
| Number of Meters (clusters) | 25,796 | 25,796 | 25,796 |
| Average water savings per toilet, per month:[b] | 362 | 301 | 298 |
| [95% confidence interval] | [184 – 540] | [185 – 417] | [182 – 414] |

[a] Statistical Significance at the 1%, 5%, and 10% level are represented by ***,**,and *, respectively.

[b] Average water savings per toilet per month is computed as $P_1*\delta_1+(P_2*\delta_2)/2+(P_3*\delta_3)/3$, where Pi is the proportion of households for which HETi equals 1 (i=1, 2, 3), and $\delta_i$ are the coefficients on the interaction term for HETi*Post-installation in each model (i=1, 2, 3)

**Table 6. Robustness Checks (standard errors in parentheses).[a]**

| | (1) | (2) | (3) |
|---|---|---|---|
| | | **Four or Fewer Matches Per Treated Household** | |
| **Model:** | **Common Trend** | **Baseline** | **Fixed Effects** |
| Constant | 4,512.4*** | 4,690.7*** | 4,670.1*** |
| | (22.8) | (60.5) | (44.7) |
| One HET Subsidy | 21.4 | -221.7 | |
| | (184.8) | (138.7) | |
| Two HET Subsidies | 106.3 | -151.0 | |
| | (147.5) | (118.7) | |
| Three HET Subsidies | 557.8* | 158.9 | |
| | (319.7) | (266.0) | |
| One HET * Post Installation | 190.1 | -357.9** | -408.9*** |
| | (190.5) | (145.0) | (98.3) |
| Two HET * Post Installation | -221.6 | -775.9*** | -463.1*** |
| | (161.6) | (121.3) | (68.6) |
| Three HET * Post Installation | -116.7 | -904.1*** | -965.2*** |
| | (337.5) | (192.4) | (158.5) |
| | | | |
| Observations | 1,240,002 | 139,573 | 133,579 |
| R-squared | 0.03 | 0.03 | 0.05 |

[a]Statistical Significance at the 1%, 5%, and 10% level are represented by ***,**,and *, respectively.

**Table 7. Cost-Effectiveness Estimates for Year 1 of the HET Rebate Program.[a]**

| Assumed years to replacement of original toilet in absence of the rebate program | Yearly Annuity Payment | Cost Effectiveness (per 1,000 gallons of water conserved) |
|---|---|---|
| 30 years | $5,777 | $7.33 |
| 15 years | $8,555 | $10.85 |
| 10 years | $11,500 | $14.58 |
| 5 years | $20,511 | $26.01 |

[a] In year 1 of the rebate program, the Town of Cary paid $88,800 in rebate costs for 592 high efficiency toilet installations.

**Figure 1. Mean monthly water use (gallons) for 683 HET rebate participants and 25,100 matched neighbors.**

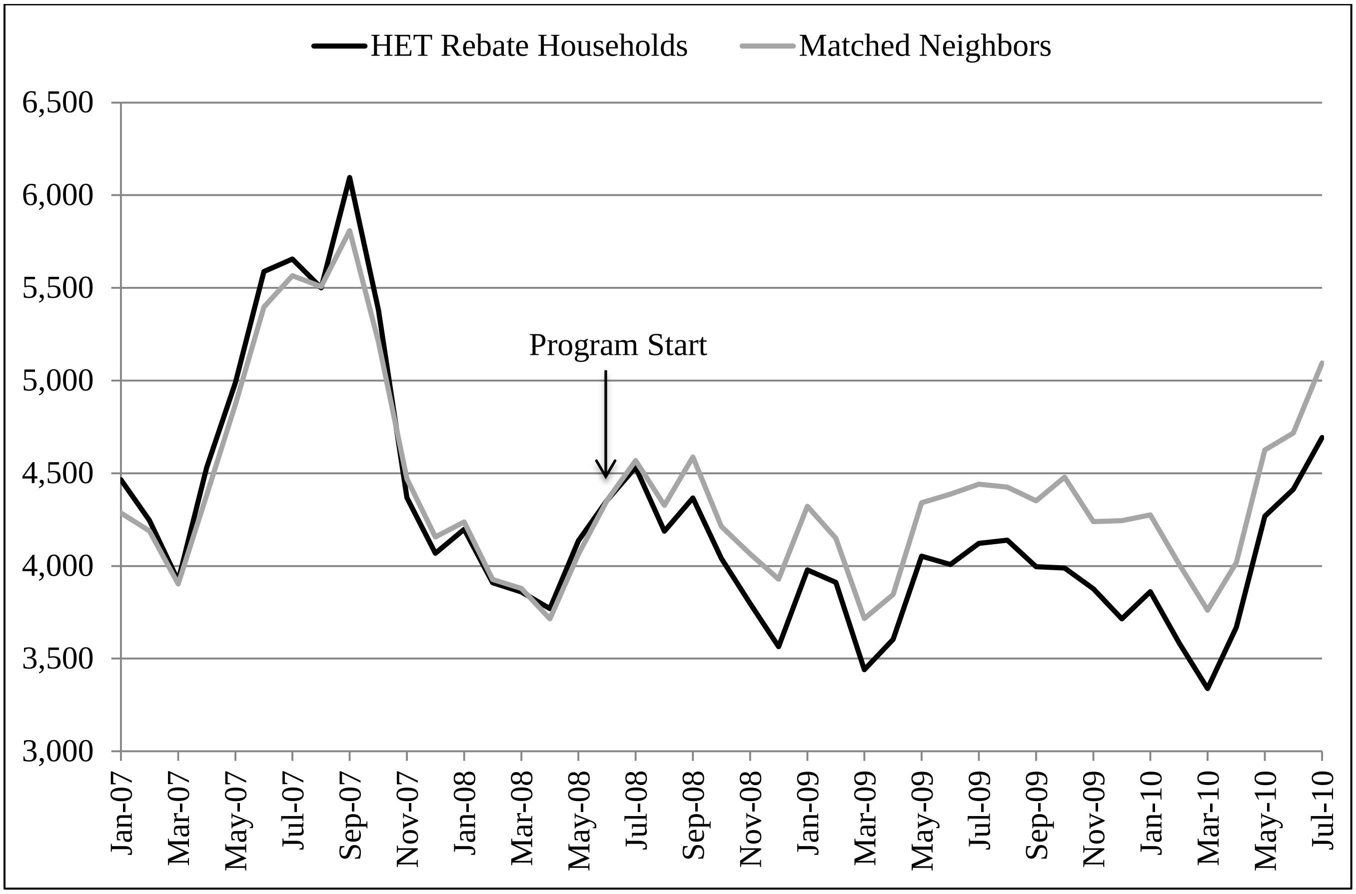
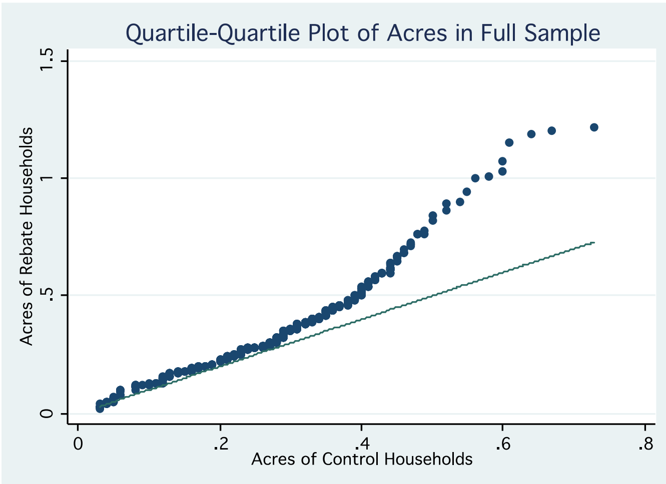
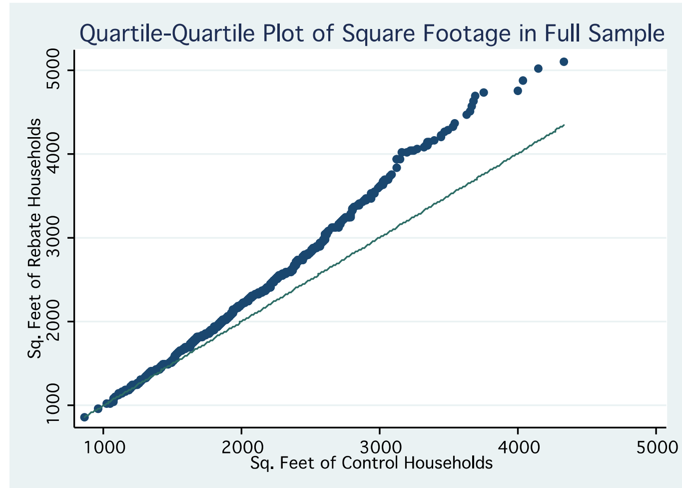


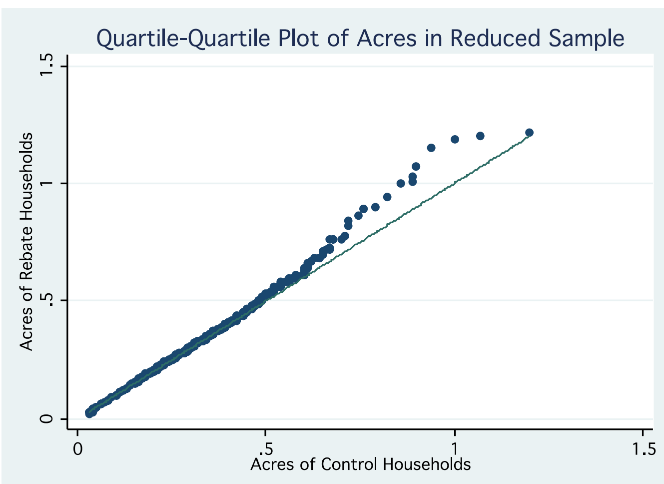
**Figure 2: Quartile-Quartile Plots of Acres and Square Feet in Rebate and Control Household**



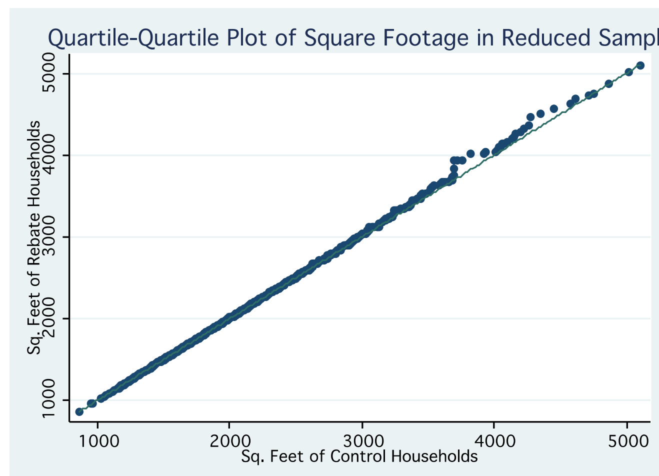

Panel A: Acres in the Full Sample




Panel B: Sq. Footage in the Full Sample




Panel C: Acres in the Reduced Sample




Panel D: Sq. Footage in the Reduce Sample

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**Appendix A: Survey Questions and Additionality Algorithm**

***Please answer the questions on this page thinking only about the toilets for which <u>you received a rebate</u>.***

4. Did you know about the Town of Cary High-Efficiency Toilet Rebate Program before deciding to replace your toilets?
   a. YES
   b. NO

5. Was replacing the old toilet part of a bathroom renovation?

| | Toilet 1 | Toilet 2 | Toilet 3 |
|---|---|---|---|
| a. YES | □ | □ | □ |
| b. NO, I only replaced the toilet | □ | □ | □ |

6. For toilets which you answered **YES** in question 5, would you have chosen a high-efficiency toilet even if the rebate **<u>were not</u>** available? (*If you answered only NO above, please skip to 7.*)

| | Toilet 1 | Toilet 2 | Toilet 3 |
|---|---|---|---|
| a. YES | □ | □ | □ |
| b. NO | □ | □ | □ |

7. For toilets which you answered **NO** in question 5, would you have replaced the toilet with a new, but not high-efficiency toilet, if the rebate **<u>were not</u>** available?

| | Toilet 1 | Toilet 2 | Toilet 3 |
|---|---|---|---|
| a. YES | □ | □ | □ |
| b. NO | □ | □ | □ |

8. For toilets which you answered **NO** in question 5, would you have replaced the toilet with a high-efficiency toilet if the rebate **<u>were not</u>** available?

| | Toilet 1 | Toilet 2 | Toilet 3 |
|---|---|---|---|
| a. YES | □ | □ | □ |
| b. NO | □ | □ | □ |

Algorithm for assigning responses to additionality groups 1-3 as described in Section 4:

If 5 = yes and 6 = yes ➔ Group 3

If 5 = yes and 6 = no ➔ Group 2

If 5 = no and 7 = yes ➔ Group 2

If 5 = no and 7 = no and 8 = no ➔ Group 1

If 5 = no and 8 = yes ➔ Group 3 (regardless of answer to 7)

If 5 = no and 7 = yes and 8 = no ➔ Group 2