The Influence of Rebate Programs on the Demand for Water Heaters
The Case of New South Wales*

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Prepared for

The 55th Australian Agricultural and Resource Economics Society National Conference

8-11 February 2011, Melbourne

Abstract

In the past decade the Australian Federal government and state governments have established a wide range of programs to cut greenhouse gas emissions from all sectors. This paper examines the role of hot water system rebate programs in shifting the existing stock of electric water heaters toward more climate friendly versions using two unique data sets from New South Wales homeowners. The first data set is based on a survey of households who recently purchased a water heater and exploits a natural experiment created by the rebate program to quantify its effects. The other data set is based on a set of stated preference questions asked of households who own an older water heater and will in the reasonably near future face a replacement decision. We find that recent rebate programs significantly increased the share of solar/heat pump systems. For households without access to natural gas, this increased share comes directly from inefficient electric water heaters. For households with access to natural gas, older existing electric water heaters would likely have been replaced with gas water heaters in the absence of the rebate programs. The rebate program appears to be much less effective when water heaters are replaced on an emergency basis. Data from discrete choice experiments was analysed using several flexible choice models. A newly proposed model that combines a latent class approach with a random coefficients approach clearly dominates the other models in terms of statistical fit. Predictions based on this model estimate are reasonably consistent with actual purchase data. Results from it point to considerable heterogeneity with respect to household preferences toward different types of water heaters and with respect to the discount rates they hold.

Keywords: Climate change mitigation, Energy conservation programs, Natural experiments, Discrete choice experiments

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* The authors would like to acknowledge support from Australian Research Council grant DP 0774142. Jordan Louviere provided helpful advice on the experimental design, Yen-Ching Sung provided assistance on initial survey development work, and Edward Wei provided invaluable assistance in collecting the data.

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I. Introduction

In 2005, Australia's per capita greenhouse gas emissions were among the highest in the world and the highest in the OECD. These high emissions are mainly driven by the high emissions intensity of energy use, resulting from Australia's reliance on coal for electricity (Garnaut, 2009.) To promote energy efficiency improvement, the Australian Federal and state governments have established a wide range of programs for all sectors. This paper focuses on hot water system rebate programs aimed to reduce emissions from the New South Wales' (NSW) residential sector.

Water heating is the largest single source of greenhouse gas emissions from the average Australian home.[1] For NSW, which includes the greater Sydney metropolitan area, electric water heaters currently account for more than a third of household energy use.[2] Switching one electric water heater to a climate-friendly water heater such as gas, solar or heat pump can reduce carbon emission by 2.5-3.0 tonnes per year on average. This implies a significant reduction at an aggregate level. While the share of gas water heaters has risen in the past three decades, shares of solar and heat pump systems remained relatively small (less than 5 percent in 2005) despite the fact that households could save on their energy bill by installing a solar or heat pump system. The high upfront cost of these systems is likely to be the key barrier. Some households may face financial constraints and those with high discount rates are unlikely to invest in a water heater that takes a long period to pay itself back.

To overcome this barrier, the Federal government and NSW initiated rebate programs in July 2007 and October 2007, respectively. These two programs, which can be combined together, would allow a household that replaces an existing electric water heater with a solar or heat pump system to cover a large part of upfront cost. The NSW program also provides a rebate for those who switch from electric to gas. In this paper, we assess the effect of these recent efforts on household water heater demand of NSW homeowners using a survey explicitly designed to collect information from owners who purchased a water heater in the past six years and from NSW homeowners with older water heaters who are likely to purchase a water heater in the future. The six year time frame for the first set of households allows us to exploit a natural experiment created by the rebate programs to quantify their effects. The stated preference questions asked the other set of households allow us to examine the likely effects on possible changes in the rebate programs on future demand.

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[1] http://www.climatechange.gov.au/government/programs-and-rebates/solar-hot-water.aspx
[2] http://www.environment.nsw.gov.au/rebates

Using the actual purchase data, our results indicated that the rebate program significantly increased the share of solar/heat pump systems by 43 percent for households who do not have access to natural gas. This implies a similar reduction in the share of electric water heaters. For those with natural gas access, the program increased the share of solar/heat pump systems by 19 percent. For this group of households, however, most would have chosen to replace their electric water heaters with gas water heaters if the rebate programs had not been in place. Gas water heaters are more climate friendly than electric due to the heavy use of coal to generate electricity but are not as efficient as solar or heat pumps.[3] Thus, the rebate program for those with gas access should be seen as moving households away from choosing gas toward solar/heat pumps rather than from their current electric water heaters toward solar/heat pumps. We also find that the rebate programs appear to work largely on households that deliberately set out to replace their water heater rather than on households that replaced their water heater on an emergency/urgent basis. This suggests that programs that educate or provided incentives for plumbers, who play a large role in the emergency situations, may be an important channel to help improve the effectiveness of future rebate offerings.

The data from the discrete choice experiments using the stated preference data were analysed using several flexible choice models, including the workhorse conditional multinomial logit model, two currently popular generalizations – latent class model and mixed logit model – as well as two relatively new models – generalized multinomial logit model, and the mixture-of-normals mixed logit model which further generalize these models. The model using mixture-of-normals as the mixing distribution is found to dominate other models. Predictions are reasonably consistent with actual purchase data. The results from the discrete choice experiments point to considerable respondent heterogeneity in their perceptions toward different types of water heaters and in their implied discount rates with respect to payback periods. The estimated median discount rate is in the range of 10-12 percent. Alternative scenarios are considered where the rebate amounts are lower than the 2007 scheme and where households replacing an existing gas system with a solar or heat pump system are eligible for a rebate.

The next two sections review the previous studies in this area and discuss the nature of the NSW water heater market. Section IV describes data collection. Results from actual purchase data and stated choice experiments are reported in Sections V and VI, respectively.

[3] Solar and heat pump heaters are considered more efficient as they mainly generate energy from a "free source." Solar water heaters with gas booster are also more climate friendly than gas water heaters.

Section VII discusses predictions for different scenarios. The last section provides some concluding remarks.

II. Previous studies

A number of studies have examined the relationship between household choice of appliance holdings, energy consumption, appliances' initial and operating costs, and fuel prices. Household reaction to a shift in relative fuel prices is traditionally considered as consisting of two components. First, in the short-run, consumers adjust their usage level holding the capital stock of appliances fixed. In the long-run, consumers may trade off higher initial capital costs with the reduction in operating cost if the operating cost of their current system has significantly increased.

Hausman (1979) jointly model these two decisions by looking at household demand for and use of home air-conditioners where each system differs in their efficiency level. Using a sample from 16 cities in the US in 1975, his estimates of the trade-off rate between initial cost and operating cost implies the discount rate about 20 percent.[4] In other words, an average consumer would be willing to pay about $4 for a dollar saved annually. Dubin and McFadden (1984) consider household demand for and use of space-water heating systems where they consider households whom water and space heaters were either both electric or both gas. They also find a discount rate about 20 percent calculated at the sample mean income for US households in 1975.[5]

Dubin (1986) is the only study that examines the choice of space and water heaters for new houses. All possible combinations of types of space and water heaters are used in the analysis. He employed a nested logit model where the upper-level nest is the choice of space heating. Then, conditional on the type of space heating, the consumers choose among three types of water heaters: electric, gas and oil. Using the Pacific Northwest region, he finds a relatively low discount rate (9.6 percent) for water heaters compared to the previous two studies, both of which used national data. There are some studies (*e.g.*, Cameron, 1985 and Hartman, 1988) that look at household demand for retrofits such as wall insulation, storm

[4] Hausman (1979) estimates a two-stage model. In the first stage, conditional on each possible air conditioner, an individual chooses usage level (electricity demand). Empirically, he finds that consumers with a higher efficient system also use air conditioning more. In the second stage, individuals choose the optimal choice among different types of air conditioners where the estimated usage level from the first stage is used in calculating operating cost.

[5] Dubin and McFadden (1984) first predict the probability of choosing a gas or electric system. The running cost in the first stage is calculated based on typical usage. In the second stage, the predicted probability is then used as an instrument in the electricity demand equation.

windows and hot water pipe wrap. Such decisions should be considered medium-run adjustments. While waiting for a long-run adjustment in a household's major appliance holdings, some consumers may find it optimal to make investments to improve energy usage of their existing appliances.

While the theoretical model developed in this early literature are useful in evaluating the demand for new technologies and estimating household discount rates, researchers find it challenging to obtain appropriate data for empirical estimation. New technology alternatives are not available in data on past appliance choices and collection of data on choices in the distant past often involves substantial recall issues. Further, government and utility energy-conservation induced programs, such as rebate or low interest loans are often too small to induce much change in choice behaviour and/or exhibit too little variation in the levels of rebate or interest rate available.

Stated preference survey data has proven a successful alternative in several studies. Revelt and Train (1998) estimate the impact of rebates and loans on residential customers' choice of efficiency level for refrigerators using data from a southern California company. They find that on average, the consumers are willing to pay \$2.46 for a dollar savings annually. This translates into a discount rate of 39 percent which is relatively high. They also find that responses to incentive variables are very heterogeneous. Brownstone, Bunch and Train (2000) collect both stated preference and actual purchase data to forecast demand for automobiles for California households. New technology alternatives such as electric cars or methanol cars are included in their stated preference survey.

Australian studies which attempt to understand a household's decision to purchase water heaters and other durable appliances at the micro level are rather limited.[6] Fiebig and Woodland (1994) model household water heater choice as a function of household characteristics using a 1989 NSW survey of appliance holding and energy. They find that these choices are very significantly different between households with and without access to gas. High income households with gas access are more likely to have a gas water heater while high income households with no gas access are more likely to own an off-peak electric heater. Also, by comparing the penetration rate with the two earlier surveys, they report that there was very little change in the penetration rate between 1984 and 1986. In contrast, from

[6] In New Zealand, Gillingham (2009) considers the effect of possible solar hot water rebate policy options. His approach is based on aggregate sales data of solar hot water systems over time. Under the assumption that different types of consumers would adopt solar heaters at different points of time, and that prices of solar heaters decline over time, he predicts that with a policy rebate starting at \$1500 (and falling slightly over time), sales of solar hot water heaters would increase to about 25,000 systems by the next 5 years (about 80% of 2007 sales).

1986 to 1989 there was a modest increase in the penetration rate for off-peak electric water heaters and a more substantial increase in the range for gas water heaters. Bartels, Fiebig, and van Soest (2006) model household purchase decisions of water heaters by collecting stated preference data from a sample of Sydney residents in 1999. The study focused on the relationship between plumber recommendations and consumer choices and looked at electric versus gas systems for households with gas access.

III. Background of New South Wales water heater market

In NSW, electric hot water systems were originally installed in most homes. However, there has been a clear trend of moving away from peak electricity to off-peak electricity and gas systems since the 1980s (see, *e.g.*, Fiebig and Woodland, 1994). Table 1 shows the distribution of water heater holdings by NSW households using data collected by the Australian Bureau of Statistics (ABS) between 1999 and 2008. There is a continuing trend of a decline in peak electricity in favor of off-peak and gas. Shares of solar heaters remained very low between 1999 and 2005 but substantially increased to 5% in 2008.

Instantaneous gas and heat pump systems were rare in the past (hence, often not listed as separate categories) but recently have started to become more widely installed. The Australian Department of the Environment, Water, Heritage and the Arts (2008) projects that for new homes built between 2006 and 2020, share of gas systems will be 70% and that instantaneous gas would be more popular than storage gas. Shares of solar and heat pump systems are predicted to increase to 15% and 5%, respectively (see Table 2.)

One explanation of the gradual shift from electricity to gas in the 1980s and 1990s is the expansion of gas coverage in NSW over time. More recent government efforts to encourage households to switch from electric systems to a more climate-friendly hot water system potentially account for the reported 2008 figure as well as the government's projected increases in shares of nonelectric systems. The Australia Federal government, NSW government, as well as local governments, recently established various financial incentives and regulations to promote energy efficiency.

Since 2001 households who installed a solar or heat pump water heater to replace an electric water heater could qualify for Renewable Energy Certificates (RECs). The RECs can be sold in its market, which gives the owner back approximately AUD 1000.[7] This program

[7] RECs are electronic certificates that represent blocks of energy generated from renewable sources, created through the Commonwealth Renewable Energy Act 2000 to reduce greenhouse gas emissions from the use of electricity. The RECs demand is generated by the regulation requirements that electricity retailers and other

covers the entire period that we examine so it can be thought of as the baseline rebate level. There is also a new building requirement called the Building Sustainability Index (BASIX) that is not directly relevant here, as we are looking at water heater replacement.[8]

The major change in the rebate program came with a set of large financial incentives. First, the Australian Government Solar Rebate program started in July, 2007, where low income families who replace an electric hot water system with a solar or a heat pump system would receive a rebate for AUD 1000.[9] Second, and to much greater publicity, the NSW government initiated a rebate program in October, 2007 which was originally announced to end at June 30, 2009 but was later extended by two years to June, 2011. Eligible criteria for the NSW program were much less restricted and could be combined with the Federal government rebate.[10] Households who replace their electric systems with a heat pump or solar system receive a rebate between AUD 600 and 1200. Those who replace their electric systems with a gas system also receive AUD 300.[11] Starting in October 2007, households could potentially combine rebates from REC, Federal and NSW governments to cover a large part of the upfront cost. In February 2009, the Federal program stopped means testing and increased the amount of its solar and heat pump rebate to AUD 1600. The amount of rebate was dropped back to AUD 1000 in September 2009.[12] There were also some additional rebate programs introduced by some of the smaller NSW municipalities after the NSW rebate program was announced. Because it is effectively impossible to sort the effects of all of these

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wholesale purchasers must surrender a number of RECs each year based on a percentage of their annual electricity acquisition or pay a shortfall charge ($40 per REC). REC's supply can be created by a variety of renewable energy sources (*e.g.* wind, hydro, crop waste). Solar or heat pump water heaters that meet specified conditions that can be recognized for the electricity generation they displace. The owners of the heaters can create RECs themselves through the internet based REC registry but most find it more convenient to assign their right to a registered agent (most suppliers) in return for a financial benefit such as a price reduction or cash rebate. RECs assigned to each water heater range from 10 to 64 certificates. The REC price varies over time but is normally around $30-$35.

[8] The BASIX program started in 2004 and required new homes to meet a BASIX score calculated on the unit's water and energy usage. Households have a range of options to make their home "sustainable" in meeting the required BASIX score. These options include installing a gas or solar hot water system, as well as installing home insulation or using dual-flush toilets.

[9] The number of available rebates is limited at 225,000 households and its eligible criteria include: (1) owners or tenants (with owner permission), (2) solar or heat pump systems must have at least 20 RECs with a 5-year warranty, (3) taxable family income less than $100,000 (from the latest lodged), and (4) the dwelling must be the principal place of residence.

[10] Water heaters installed to comply with BASIX are excluded so no overlap exists with the new home program.

[11] The eligibility criteria include: (1) owners, (2) 5-star rating gas, solar or heat pump systems with at least 20 RECs, and (3) must continue ongoing operation for the first 5 years (audit).

[12] From February 2010 (which is beyond the period that our data is collected), the rebates for solar and heat pump are $1000 and $600, respectively.

different programs, we will consider their aggregate impact and take October, 2007 as their start date through the end of 2009, when our survey went into the field.[13]

There is clear external evidence that the NSW rebate program is being used. In March, 2009, Department of Environment and Climate Change NSW (2009) reported that 21,196 households applied for rebates. Shares of solar, heat pump and gas systems are 61%, 18% and 21%, respectively. While this positive response is promising, two important questions cannot be answered by this figure alone. As Garnaut (2009) and Independent Pricing and Regulatory Tribunal of New South Wales (IPART, 2009), who reviewed the program, pointed out that it is difficult to assess the success of the program because of the lack of a clear counterfactual. The rebate uptake data alone does not tell us (1) whether the participation rate is high; and (2) whether there is a deadweight loss to society in the sense that households who applied for rebates would adopt the energy-efficient system anyway without rebates. Our analysis tries to answer these questions.

IV. Data

We collected data through a very large web-based panel belonging to a major survey research company. During December, 2009 and January, 2010, 9400 total invitations were sent to the panellists who were NSW homeowners. The respondents were first asked about the type of their current water heater, the age of that water heater, and whether they purchased that water heater for their home or if it was built-in. For those who had purchased a water heater, the year of purchase and other information about the system was elicited. For those who had not purchased a water heater since moving into their home, the respondent was asked to estimate the age of their hot water system. If the respondent could not do this, we approximated the age of the system by the year in which they moved into their dwelling. Table 3 reports the distribution of water heater holdings by the (estimated) age of the water heater from this sample. The data is consistent with the ABS survey data discussed earlier; the share of electric based systems is declined among newer systems in favour of gas. Within gas systems, instantaneous gas has gained in popularity and solar and heat pump shares have increased strikingly in the last 5 years.

[13] The 2007 Federal program started three months earlier than the NSW program but was less publicized and initially targeted at the low income segment households which has a much higher propensity to rent. To the extent that there was a substantial increase in solar/heat pumps caused by the 2007 Federal program before the 2007 NSW program went into effect, we will under-estimate the effect of the set of rebate incentives that differed from the original baseline 2001 Federal incentive program.

We design our study to consist of two components. First, we wanted to exploit the natural experiment created by the introduction of the rebate program to quantify the effect of the program on *recent* water heater demand. Second, we wanted to understand *future* water heater demand by targeting the views of those likely to soon be in the market. Given water heater durability of 10 to 20 years, those who recently replaced their water heater are unlikely to replace their system again in the next couple of years.

Respondents who purchased the system in 2004 or afterward (subsample of the last column) were asked questions related to their recent purchase. We call this group the revealed preference (RP) respondents. Respondents with an old hot water system (the left column) and likely to be in the market in the near future, were further assigned to answer a choice experiment survey. This group is called stated preference (SP) respondents.

The figures reported in all previous tables are aggregated over those with and without gas access. Previous studies suggest that to understand the decision at the household level, it is crucial to analyse these two groups separately, as they face different choice sets. The numbers of observations differentiated by gas access are provided in Table 4.[14] RP respondents who installed the water heaters in brand new homes are excluded from the analysis as choice of which type of water heater may have been made by the builder rather than the eventual owner in this case. The top panel shows distribution of old systems (which are the system previously owned by RP respondents and the current system owned by SP respondents.) For both RP and SP respondents, those with gas access are less likely to own an electric system. And for both groups, not surprisingly, those without gas access are likely to own an electric heater. The picture looks different for new systems chosen by RP respondents. Shares of nonelectric systems significantly increase. In the next section, we investigate whether this increase can be attributed to the rebate programs.

V. Evidence from a natural experiment

Our RP respondents are those who replaced their water heaters between 2004 and 2009. This cut-off of six years is chosen so that we can compare the choice decision of

[14] We also screened out owners who reside in apartments, flats/units as they are less likely to be able to install solar water heater or heat pumps. We further excluded a small number of households with eight or more people due to the presumption that their temporal demand characteristics for hot water were likely to be different from other households. Another screening question asked if the respondent is responsible for his/her household's energy bills. We include only respondents who indicated that they were “responsible” or “jointly responsible” in our estimation sample under the presumption that someone who is not responsible for their household's energy bills is not likely to be involved in decisions about purchasing a hot water system. There are only 7 observations of people who purchased gas (LPG) systems and met with these criteria. We decided to exclude them as well.

households who purchased the heater before and after the large incentive programs came into effect. Among 912 cases, 664 previously owned an electric system and 248 previously owned a non-electric system (mainly gas). October, 2007, which was the effective date of NSW rebate program, is chosen as a cut-off for "before" and "after" policy. Most households were eligible for these rebates and the NSW government broadly publicized the program. It is important to remember, however, that as noted earlier, we are looking not at just the NSW program but also the sizeable new Federal rebate program. That program was implemented just prior to the NSW program but its later expanded eligibility criteria meant that for most households it that it was effectively implemented afterwards. The baseline is not a no rebate condition but rather the long standing Federal rebate that was implemented in 2001.

Ideally, we would like to compare a treatment group who had access to the NSW and other contemporaneous rebate plans to a control group who did not have access to the increased rebates. In other words, we rely on the difference-in-difference (DID) approach (Imbens and Wooldridge, 2009). The basic idea behind DID is that there is a need to account for what would likely have happened if the policy of interest had not been put in place. In particular, if the overall share of electric water heaters is observed to decline, is that because of the new rebate policies or because the purchase of new electric water heaters had already started to decline before the new policies had been put in place?

Our treatment group is clearly households who previously owned an electric system as they are the ones eligible for the rebates. We consider two possible control groups. The first is comprised of households who own nonelectric water heaters. This group is ineligible for a rebate for the whole period of the study. The second is formed by splitting households who previously own an electric system before the NSW rebate policy took place (hence, no one is eligible) into two time periods (2004-2005 and 2006-September 2007) and looking at the change in behaviors during this earlier period. This second group appears more appropriate for two reasons: (1) their underlying trend should be more similar to our treatment group; and (2) the number of observations of households with nonelectric water heater with no gas access is very small. Also, these two adjacent time periods are similar in most respects.[15]

[15] Environmental attitudes appear to be fairly stable over the time period of our analysis. NSW was controlled by the Labor Party during the entire time period while at the national level, the Labor Party which put more emphasis on climate change than the Liberal-National coalition, took power in December 2007. Real per capita income grew fairly steadily over the time period with Australia experiencing somewhat less of a boom and a much smaller drop due to the financial crisis than most industrialized countries. To the extent consumers felt more financially constrained in late 2008 and 2009, we will tend to underestimate the impact of the new rebate programs. Electricity and natural gas prices rose consistently over the time period of our analysis but there was

The DID estimate for households with gas access is presented in Table 5.[16] The three top rows under the header "Before" indicate that before October 2007, on average the probability that a household would replace the old electric system with a new electric system is 28 percent. The probability that they would switch to gas is 69 percent. Only 3 percent would switch to a solar or heat pump system. The next column under the heading “After” refers to the situation where rebate policies were in place. The probability of choosing solar or heat pump increases to 26%. That increase comes from electricity (9%) and from gas (14%). These differences are reported in the last column.

The bottom panel compares household behaviours between two periods before October, 2007. We can see that for this control group, share of electric water heaters has already been reduced by 17%. Shares of gas and solar/heat pump have increased by 13% and 4%, respectively.

The DID estimate takes the difference in behaviours of the treatment and control groups. After taking into account the time trend, the policy has no significant effect in reducing the probability of choosing an electric heater. The policy however does increase the probability of choosing a solar or heat pump system (+19%) by drawing down the fraction who would have chosen a gas system.

Table 6 is an analogue analysis for households without gas access. Comparing before and after October, 2007, the probability of choosing a solar or heat pump strikingly increases from 10% to 60%. Even after taking account of the time trend, the effect of the policy on the probability of choosing a solar or heat pump is large at 43% and statistically significant.

One factor that is likely to influence choice of water heaters is whether the replacement is done on an emergency/urgent basis. Households in an emergency situation have less time to study all available options and may (correctly) be fearful that if they replace their existing hot water system with a new technology like solar or a heat pump, it will take longer to get the new system working. It is also likely to be the case (Bartels, Fiebig and van Soest, 2006) that plumbers play a much larger role in the replacement decision in an

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persistent claims that electricity prices might dramatically increase if Australia implemented a climate policy with carbon trading. Such an expectation would tend to overestimate the impact of the new rebate programs.

[16] Probability estimates and their associated standard errors are calculated by fitting a multinomial (or binary) logit model as a function of two time dummies and predicting relevant probabilities. The standard errors of the estimates of probabilities or differences in probabilities, which are the nonlinear combination of parameters, are calculated by using the delta method. We also try to incorporate household size, income, and expectation about electricity price. Only household size significantly influences solar/heat pump for the sample with gas access, but the likelihood ratio test rejects the need for a larger model. In this and subsequent tables standard errors are displayed in parentheses. The standard convention of marking significance at the .05 level with ** and the .10 level with * is followed.

emergency context and that in contrast to appliance stores, are less likely to want to deal with paperwork involved with rebates. Tables 7 and 8 further examine whether the effect of a rebate policy differs between households whose replacement was done based on an emergency and those who replaced their system on a nonemergency basis.

First, notice that the probability of choosing electricity is higher for the case of emergency compared to nonemergency (.44 vs. 0.10 for before October, 2007) and (.38 vs. .08 after October, 2007). The DID estimate for the effect of a rebate policy on the probability of choosing a solar or heat pump is significant at 24% for the nonemergency case. The effect for households whose replacement was done on an emergency basis is 9% but statistically insignificant. This might be partly due to a small number of observations. For households with no gas access, recall that our DID estimate of 43% is statistical significant. DID estimates in Table 8 for nonemergency and emergency cases are statistically significant with estimated effects of at 46% and 19%, respectively.

For households with a non-electric system (almost exclusively gas), there is no significant changes in their behaviours between "before" and "after" policies. This group's probability of choosing a new gas system was 91% during 2004-October 2007 and 95% during October, 2007-2009. This is not surprising given that they are unaffected by rebate policies.

It is possible that the rebate programs increased the fraction of water heaters replaced on a nonemergency basis. Without financial incentives, most households are unlikely to replace their water heaters before it breaks down. This means that the replacement is likely to be done on an emergency/urgent basis. Rebate programs tend to either limit the number of available rebates or to specify particular deadlines. This creates an incentive for some households to replace their water heater before their old one actually breaks down. We test whether the fraction of nonemergency replacement of those who own electric water heaters increased over time. Table 9 shows that compared to 2004 the probabilities of nonemergency replacement only significantly increased in 2009. The fact that the NSW rebate program approached its original deadline and the Federal rebate program stopped means-testing in 2009 are likely to drive this result.

In sum, we find that there is a significant effect the rebate policy has on the probability of choosing a new technology system such as solar or heat pump. However, for households with gas access, that increase in probability does not imply the significant reduction in probability of choosing electricity. Instead, the increase comes from households who would have chosen gas if the policy were not in place. This implies that there are some residents who are likely to stay with electric heaters. Households with high discount rates may still choose an electric water heater because it still has a lower up-front cost than a climate-friendly water heater. Further, some households may make a decision not only based on the trade-off between upfront costs and running costs, but also because of their perception toward certain types of water heaters. For example, they may feel uncertain about the performance of solar and heat pump systems, as they may be unfamiliar with these products, or, they may choose not to have a solar tank on their roof.

Some previous studies (*e.g.*, Dubin, 1986) were able to use revealed preference to estimate discount rates because in their data they know exactly what heater model each household has and electricity rates were known and common to all households. In our data, we do not know what heater models they have, and from preliminary survey work, most respondents cannot recall this information. When we asked about the available options at the time when they made a purchase, many respondents indicated that they were unsure whether solar and heat pump systems were available. There are eleven retail electricity suppliers in NSW who often compete against each other in the same locality and offer a myriad of different tariff schedules. Therefore, we are unlikely to impute up-front costs, running costs and choice sets for each household accurately. Hence, we have chosen to estimate discount rate and examine the issue of preference heterogeneity using stated preference data and discrete choice experiments (DCE).

VI. Evidence from discrete choice experiments

Reliable stated preference data requires that the survey is understandable and credible to respondents (Louviere, Hensher and Swait, 2000; Mitchell and Carson, 1989). The scenarios presented must also be plausible and choices must be relevant. The process of choosing a hot water system nowadays is more complicated than in the past because so many options are available. We present detailed information to respondents on the characteristics of different systems. For households with gas access, the information on different types of electric heaters, gas heaters, solar and heat pump was presented. For those with no gas access, information about gas heaters was not presented.

For electric systems, households will also have to choose what type of tariff they want to operate, which often involves the installation of a special meter. The standard (Peak) tariff means electricity supply is available 24 hours at a single price. Off-peak "1" is the cheapest electricity and provides power on that meter only for limited hours (*e.g.*, 10 pm. – 7 am.). Off-peak "2" connects to both continuous and off-peak electricity supply, with off-peak electricity being supplied at a lower price than peak power but a higher price than off-peak "1" power. Tariff choice can also influence the size of the water tank the household wants to purchase. Off-peak "2" requires a tank with dual elements so that one element is connected to the peak electric supply and the other is connected to the off-peak electric supply. If households choose to connect to the off-peak tariff, they are suggested to buy a larger tank as water is only heated at night (or mainly at night). While homeowners generally know whether they have current access to off-peak power, confusion between off-peak "1" versus off-peak "2" exists, which is not surprising since different electric suppliers have different names for their tariffs. We will combine these two types of off-peak tariffs into a single off-peak estimate when making comparison to RP based estimates.

For gas, besides the traditional storage system, instantaneous systems are also available. The instantaneous gas system only heats the water required and does not use a storage tank (also known as flow or tankless system). Households which used a large amount of water are suggested to buy the ones with high flow rates. All solar systems come with a booster that kicks in to heat water when there is not enough sunshine. Households also face choices between a gas booster and an electric booster. The number of solar panels and the size of tank required depend on household water usage. The heat pump, the least known hot of the systems, heats water by extracting energy from surrounding air. It works on the same principle as a refrigerator or air conditioner but in reverse. This system requires some electricity to operate and households can choose peak/off-peak tariff.

In order to encourage respondents to think about a plausible water heater purchase situation, we first asked them: *"Would you consider replacing your hot water system within the next couple years before it breaks down?"* If they selected 'likely', the survey then asked them to make choices between different water heaters as if they were purchasing the system now. For respondents who selected 'unlikely', the survey asked the respondent to put themselves in a non-immediate replacement *"situation where your current hot water signaled some problems (e.g., discoloured water due to rusty tank) and the plumber has suggested you to buy a new one instead of fixing it."*

The two factors that influence the relevant choice options potentially available to a particular household were: (1) access to a natural gas hook-up which determined whether gas water heaters were possible options; and (2) number of household members and their hot water usage pattern which determined what size water heater was relevant. Water heater options shown to respondents were then conditions on these two factors.

VI.A Experimental designs

The key attributes of water heaters are upfront costs and running costs. The main part of upfront costs is the cost of the tank. The appropriate tank size depends on the selected fuel types and water usage. For a given fuel type, it is recommended that the household installs a hot water system which suits their needs. For example, the NSW Department of Environment and Climate Change (2008) states: "To maximize emission and running cost savings, the system should be large enough to provide hot water to meet the household's needs. A system that is too big costs more to buy and run and will generate more greenhouse gas emission." For the same level of usage, the appropriate tank size also varies with type of hot water systems. For heaters which can generate heat 24 hours a day and everyday (peak electric and gas), their tank sizes can be small. If heat can be generated only during particular hours or certain days, then large tanks are required. Larger tanks are also more expensive than smaller ones. Table 10 summarizes suggested size for different fuel types and water usages from various brochures from suppliers and governments.

Installation is the other part of upfront cost. This cost component is generally smaller but tends to be quite household-specific.[17]

Running cost is determined by the energy required, the system converting efficiency and fuel tariffs. More specifically, the running cost of system *s* for household *h* is given by:

$$\text{Running cost}_{s,h} = (\text{E*TempRise})\text{*efficiency}_s\text{*tariff(fuel}_s\text{)* water usage}_h\ ,$$

where E is 4.187 kJ/kg K, the heat energy required to raise the temperature of one liter of water by 1˚C at standard temperature and pressure; and TempRise denotes the water temperature needed to be raised (45˚C on average). Efficiency refers to the ability of system *s* to deliver heat energy. If a system requires twice as much energy to what can be extracted, then the system has an efficiency of only 50%. While actual running costs are difficult to accurately be observed, estimates are available from several sources (*e.g.*, Rinnai Australia Pyt Ltd, 2008; Wilkenfeld and Associates Pty Ltd, 2005). The available estimates largely differ by their assumptions of projected tariff for electric and gas and average household water usage.

To construct a plausible scenario for each household, we asked respondents to self-select themselves into three usage-level groups. They were asked whether they consider their

[17] Typically, a plumber needs to go to the house to assess the installation difficulty before giving a cost quote.

household's hot water usage as small, medium or large.[18] To determine whether a gas system is a possible option for a household who currently does not use gas system, we first asked if the household had a gas connection to their dwellings. For those who stated that they do not currently have a gas connection, we ask if they know whether they have a gas line on their street. The respondents are classified as "gas access" if their answer is affirmative to either of these two questions, and as "no gas access" otherwise. Essentially, respondents are assigned to one of 6 types of experiments: 3 usage levels x 2 gas accessibility levels (yes/no).

For those with gas access, their choice scenario consists of seven water heater options: three electric options (peak, off-peak "1", off-peak "2"), two gas options (storage and instantaneous), and solar and heat pump. For those with no gas access, two gas options are excluded from their choice sets. There are other system attributes that we could have included such as different types of boosters or special tariffs for solar. This was not done in order to keep the choice task as straightforward as possible, simply given that our interest centered on the role of rebate policies and estimation of household discount rates.

For a given usage level, each option differs by their upfront costs (which is displayed with and without any rebate), mail-in rebate amounts and annual running costs. Because only the differences in attributes matter, we keep the attributes of one option (off-peak "2") fixed for all scenarios. The attributes of other options can take one of the four levels. Upfront costs were varied in a plausible range according to type and size of hot water system in Table 10. The running costs were also varied to cover the range of estimates from various sources. Mail-in rebate is the amount of money the respondent pays at the time of purchase and later mails in a rebate form to receive money back, generally taking two months to process, mimicking the existing rebate programs. Electric systems never have a rebate. The details are listed in Table A1 in the Appendix.

Although respondents with different usage levels were mapped to a different display of costs they face, all designs are generated from a 4^(6*3) orthogonal mains effects design.

[18] Our survey stated that: "Typically, the amount of water usage is based on the number of people in your household.

1-2 people	small water usage
3-4 people	medium water usage
5-7 people	large water usage

Each classification above assumes that: Each person takes a 10 minute shower per day with a standard showerhead. Hot water is not used for dishwasher, washing machine, spa or pool. However, if your household has 4 people and also uses hot water for dishwashing and washing machine, you may need to select "large" water usage. Similarly, if your hot water system is connected to a pool or a spa, you may need to select "very large". Respondents are then asked to select the options among "small", "medium", "large" or "very large."

The design consists of 64 choice sets and was blocked into four blocks.[19] Each respondent was asked to complete 16 choice scenarios. The upfront cost before rebate is displayed as the sum of net upfront costs and the rebate.

Designs are alternative-specific where all systems have their pros and cons and no option clearly dominate. For example, electric-peak systems are more expensive to run but the cost of its smaller tank makes it less expensive. Off-peak "1" is the cheapest among electric systems, but if the household runs out of hot water during the day they will have to wait until night. A gas instantaneous system is more expensive to buy than a gas storage system but is more compact and has a lower running cost. A heat pump system does not require an exterior panel like solar, but it makes a noise similar to a refrigerator.

Respondents are given detailed information about all of the systems and shown a pictorial representation. The pros and cons of the attributes of water systems are briefly explained before respondents are asked a set of choice tasks. Figures 1 and 2 show an example of information presented to the respondents for the solar water heater and an example of a choice scenario, respectively.

Based on our initial survey development work, one important feature of any water heating system was its warranty (and implicit durability). To keep this factor constant across all systems, respondents were told that all systems came with a 10-year warranty for parts and 5-year warranty for labour. Respondents were further told that if a particular alternative provided for a rebate that they would be eligible for it.

VI.B SP Model formulation

The purchase decision of energy-using durables is typically modeled under the random utility framework. Each household evaluates conditional indirect utility function for each alternative and choose the alternative that gives the highest utility. In our application, we specify the conditional indirect utility of household *n* from water heater *j* in scenario *t* as:

$$U_{njt} = \alpha_{jn} + \delta_{1n}\text{cost\_after\_rebate}_{njt} + \delta_{2n}\text{dmailin\_rebate}_{njt} + \delta_{3n}\text{runcost}_{njt} + \varepsilon_{njt}$$

$$\text{for } n = 1,\ldots,N;\ j = 1,\ldots,J;\ t=1,\ldots,16, \qquad (1)$$

where α_{jn} denotes the alternative specific constant, representing the unobserved value household *n* places on alternative *j*; $\delta_n = \{\delta_{1n}, \delta_{2n}, \delta_{3n}\}$ are preference weights placed on out-of-pocket expense, rebate process and running costs, respectively; and ε_{njt} is the unobserved

[19] In blocking designs into four blocks, we repeatedly randomize the profiles so that all values of attributes appear in each version. This avoids situations where one version consists of all low or high levels of certain attributes.

component. This specification is similar to Revelt and Train (1998) and Bartels, Fiebig and van Soest (2006) where the rebate amount is incorporated in the net upfront cost term. 'dmailin_rebate' (dummy for rebate) only captures people's perception about the two-month mail-in rebate process holding their out-of-pocket expense constant. One would expect its coefficient to be negative if people dislike the two-month delay. It may be positive if the rebate plays the same role as an "on-sale" sign. 'runcost' is the annual running cost for each heater. The ratio $\delta_{3n} / \delta_{1n}$ is the marginal willingness-to-pay (WTP) to save \$1 per year. Given that all heaters are assumed to have the same durability of q years, this ratio can be converted to discount rate (r) by solving: $wtp = \frac{1}{(1+r)} + \frac{1}{(1+r)^2} + ... + \frac{1}{(1+r)^q}$. The first term represents the value of a dollar saved in the first year discounted by (1+ r). The second term is the value of a dollar saved in the second year discounted by $(1+r)^2$, and so on.

Let α_n denote the vector of all alternative specific constants and ε_n denote the vector of the unobserved components from all choices in all scenarios for person n. Let $\beta_n = (\alpha_n, \delta_n)$ denote all coefficients on observed product attributes and X_{njt} collect all the terms of observed attributes. Then, equation (1) can be rewritten as

$$U_{njt} = \beta_n X_{njt} + \varepsilon_{njt} \qquad \text{for } n = 1,...,N; j = 1,...,J; t=1,...,16 \qquad (1')$$

The probability that a sequence of choices $\{j^*_{n1}, j^*_{n2},..., j^*_{nT}\}$ is observed is given by

$$\begin{aligned} & prob(U_{nj_1^*1} > U_{ni1} \;\; \forall i \neq j \;\text{ and } U_{nj_2^*2} > U_{ni2} \;\; \forall i \neq j \ldots \text{and } U_{nj_T^*T} > U_{niT} \;\; \forall i \neq j) \\ & = prob(\beta_n X_{nj_1^*1} + \varepsilon_{nj_1^*1} > \beta_n X_{ni1} + \varepsilon_{ni1} \;\; \forall i \neq j \;\text{ and} \\ & \qquad \beta_n X_{nj_2^*2} + \varepsilon_{nj_2^*2} > \beta_n X_{ni2} + \varepsilon_{ni2} \;\; \forall i \neq j \;\text{ and} \\ & \qquad \ldots \text{and } \beta_n X_{nj_T^*T} + \varepsilon_{nj_T^*T} > \beta_n X_{niT} + \varepsilon_{niT} \;\; \forall i \neq j) \end{aligned} \qquad (2)$$

Different choice models are derived from different assumptions researchers place on β_n and ε_n. The traditional (McFadden, 1974) multinomial logit model (MNL) assumes that β_n is homogeneous across n and the idiosyncratic error component ε_{njt} is i.i.d. extreme value. Under these assumptions, the probability in (2) has a closed form expression. While these assumptions facilitate estimation, they impose a very special structure on how changes in elements of observed product attributes can affect choice probabilities. For instance, the IIA property implies that if the share of solar water heaters were predicted to be increased, the share of all other heaters would be predicted to drop proportionally. Also, with our panel data, the basic MNL does not incorporate that the unobserved components of observations from the same respondents are likely to be correlated.

In this paper, we consider several alternative models which relax the IIA assumption and allow for unobserved heterogeneous tastes over the observed product attributes. The models we consider include the two that are widely used – the latent class model (LC; see Kamakura and Russell, 1989) and the mixed logit model (MIXL; see McFadden and Train, 2000) as well as two relatively new models – the new generalized multinomial logit (G-MNL; see Fiebig, *et al.,* 2010) and the mixture of normals logit model or "mixed mixed" logit (MM-MNL; see *e.g.*, Train, 2008) model. These models specify the heterogeneity distribution of β_n differently, but all continue to assume that the idiosyncratic error component ε_{njt} is i.i.d. extreme value.

In most application, MIXL assume that β_n is distributed as multivariate normal in the population, $\beta_n \sim MVN(\beta, \Sigma)$. LC, on the other hand, assumes that there are several segments of consumers. β_n differs across segments but are the same for all consumers within the segment. Essentially, LC assumes that the underlying distribution is discrete. This allows for a more flexible shape compared to normal but is often found to understate heterogeneity in the population (Elrod and Keane, 1995.) G-MNL extends MIXL by nesting it with the scale heterogeneity model (see below). MM-MNL generalizes MIXL by specifying the mixing distribution in MIXL to be a discrete *mixture*-of-multivariate normals. One can also think of MM-MNL as extending LC models to incorporate unobserved heterogeneity within each class. The different assumptions on β_n can be summarized in Table 11.[20]

For G-MNL, σ_n is a scalar, scaling the whole β_n vector up and down; γ is the parameter that allows η_n to be scaled up by σ_n (when $\gamma = 0$) or η_n to vary independently (when $\gamma = 1$). In practice, σ_n is assumed to follow lognormal distribution, $\ln(\sigma_n) \sim N(\bar{\sigma}, \tau^2)$ where $\bar{\sigma}$ is normalized to one. Also, the logistic transformation used to restrict γ lies in [0,1], *i.e.*, we estimate γ^* where $\gamma^*= \exp(\gamma)=(1+\exp(\gamma))$. Effectively, G-MNL adds two parameters to MIXL, τ and γ^*. If τ equals zero, γ is not identified and G-MNL approaches MIXL. If $\eta_n = 0$, then $\beta_n = \sigma_n \beta$, which is what Fiebig *et al.* (2010) called "scale heterogeneity" model. We

[20] While mixture-of-normals mixed logit potentially generalizes these models, some restrictions on parameters are often imposed in practice. This is to avoid estimating too many parameters. Fiebig, *et al.,* (2010) also pointed out that another interpretation of the generalized multinomial logit model (G-MNL) is that its taste distribution is a continuous mixture of scaled normals. This implies that the discrete mixture-of-normals mixed logit generalizes G-MNL when the number of class goes to infinity.

consider two common specifications of mixed logit and G-MNL models. The first version constrains the off-diagonal elements of Σ to zero (the coefficients are assumed to be uncorrelated.) The second version estimates the full variance-covariance matrix. For the MM-MNL model, we consider a parsimonious version with a mixture of two independent normals, *i.e.*, Σ_s is diagonal. The coefficients in this model, however, are correlated by being in the same segment.

For MNL and latent class models, the choice probability has a closed form expression and the estimation is done by maximum likelihood. For the other three models, there is no closed form expression for their choice probabilities. The parameters are estimated by maximum simulated likelihood (see details in Fiebig, *et al.* (2010) for G-MNL model; and Keane and Wasi (2010) for the MM-MNL model).

VI.C Choice experiment results

Table 12 reports choice frequencies aggregating over all scenarios. The fractions that an electric system is a preferred choice are 10% and 23% for respondents with gas and no gas access, respectively. Solar is more frequently chosen than a heat pump for both groups. For those with gas access, instantaneous gas is seen to be preferred to storage gas.

Tables 13 and 14 report the results of a representative set of models for respondents with and without gas access, respectively. We have estimated several versions of each model (LC with different number of classes; MIXL and G-MNL with uncorrelated and correlated errors) but only present a subset of the estimates of the version preferred by Bayesian Information Criteria (BIC). We also report Akaike Information Criteria (AIC) and Consistent Akaike Information Criteria (CAIC) which impose lesser and greater penalties than does BIC on models based on their number of parameters.[21]

The first column in Table 13 reports the estimates from the MNL model. The two cost variables have negative coefficients as expected. The dummy of mail-in rebate is insignificant.[22] The average WTP for $1 saved annually is -3.99*10/-8.62 = 4.62.[23] Assuming the durability of 15 years, this implies the discount rate of 20 percent. Next are the estimates

[21] *AIC = 2k-2log(L); BIC = klog(Nobs)-2log(L), CAIC = klog(Nobs+1)-2log(L)* where k is the number of model parameters, L is model likelihood, and Nobs refers to the number of observations.

[22] This is the expected result if respondents do not view getting the rebate back in the mail as an inconvenience and expect little delay in getting the rebate. Some of the more flexible model present a more nuanced view of this attribute.

[23] To improve estimation accuracy, all variables are scaled (downward) to have similar ranges. For example, upfront cost was scaled downward by a factor of 10 relative to running cost, so we have to rescale results to account for this in calculating various statistics of interest.

from the LC model with six classes. LC achieves a much higher log likelihood than MNL. The three largest classes make up 70% of the population. The largest class places a large weight on upfront cost and tends to prefer gas, solar and heat pump to electric heaters. The second largest class has a very large negative intercept on peak electric heaters, implying that this class is extremely less likely to choose peak electric heaters in all scenarios. They also place a higher weight on running cost relative to the first class. Class 3 prefer solar or heat pump systems to other systems. Class 4 cares more about upfront costs rather than type of water heaters. Class 5 does not like peak electric and heat pump heaters. The last class which represents only 6% of the population has large positive intercepts for all alternatives, implying that they do not like the omitted water heater, which is off-peak "2" electric.

The third model is the mixed logit model with a full variance-covariance matrix. Comparing to the LC model, the log likelihood is improved by a very sizeable 1477 points. The mean estimate of the mail-in rebate dummy is still insignificantly different from zero but its variance is statistically significant at .4. The variances of other variables are also large and statistically significant, indicating that respondents are very heterogeneous. The estimated covariance matrix has been omitted to conserve space but is available upon request. This model implies on average that WTP for $1 saved is $7.16. Next is the result from the G-MNL model. It adds two parameters and outperforms MIXL on all three information criteria.

The last column reports the estimates from the MM-MNL model.[24] This model achieves even a better likelihood than the G-MNL model, yet uses a smaller number of parameters. It, therefore, dominates other models on all three of the information criteria measures. Additionally, there are noticeable differences between the mean estimates of the two segments.[25] The first segment, representing 66% of population, assigns positive weights on the heat pump while the second assigns negative weights. Their average WTP for $1 saved annually are $8.1 and $5.5, respectively, which can be converted to discount rates of 9% and 16%, respectively.

Table 14 reports the results of the respondents with no gas access. The pattern of likelihood improvement for this group is similar to the previous table. BIC also prefers the

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[24] We also try parameterizing, w_{ns} , the segment probability, as a function of usage level and current water heater type, but this only results in minor improvements in the model fit.

[25] The interpretation of the two classes for this model is also more intuitive than in the standard LC model. As an example in the LC model, class 3 and class 4 have statistically significant parameters of roughly equal in magnitude but of opposite signs on the mail-in-rebate attribute. In contrast, the larger of the two MN-MNL's two classes has effectively a zero coefficient on the mail-in-rebate attribute while the smaller of the two classes has a negative and significant parameter which accords well with the economic notion of some respondents having financial constraints and the marketing notion that some consumers actively do not like mail-in-rebates.

LC model with 6 classes. G-MNL outperforms MIXL and LC, but G-MNL is again dominated by MM-MNL which achieves a superior fit with fewer parameters. The estimates of average WTP for $1 saved from running costs from MNL and mixed logit models are $6.45 and $8.62, respectively. It is interesting that the respondents in this group also split into two segments with opposite perceptions toward heat pump heaters. The estimates of average WTP to save for $1 annual running cost from MM-MNL's two segments are at $9.3 and $3.1, respectively.

To further examine the distribution of taste heterogeneity, we adopt what Allenby and Rossi (1998) call an "approximate Bayesian" approach: A model's estimated heterogeneity distribution is taken as the prior, then the posterior means of the individual-specific vectors of preference weights are calculated conditional on each respondent's choices. Train (2003), Chapter 11 provides an algorithm for making this calculation. The estimates from MM-MNL, the preferred model, are used in this illustration.

We first look at the heterogeneity distribution associated with each alternative. These posterior distributions of the person level coefficients of each system for respondents with gas access are plotted in Figure 3. More than 70% of respondents assign positive weights on the two gas systems and the solar system. We also see a small fraction of respondents who extremely prefer instantaneous gas or solar. In contrast, almost all respondents (90%) assign negative weights on a peak electric system. For off-peak "1" and heat pump, there are people who both like and dislike them. While the distribution of taste for off-peak "1" is quite symmetric with mass around zero, the distribution of taste for the heat pump is a multi-modal with a substantive mass on the positive and negative sides.

Figure 4 plots similar distributions for respondents with no gas access. Over 80% of respondents like solar and dislike peak electricity. Similar to the former group, there are people who like and dislike the heat pump but the distribution is more dispersed on both sides of the support. The posterior distributions of individual-specific WTP to save $1 annually are plotted in Figure 5. The distributions for both groups show that respondents are very heterogeneous. The substantial mass lies between $4 and $10. For both groups, there are a small fraction with very high WTP and a small fraction with negative WTP. These should not be interpreted as features as the true WTP. Rather these features are likely to be generated by group of respondents who have very strong preferences in favor of solar or the heat pump. These respondents almost always choose solar or the heat pump in the given the (fairly narrow) range of upfront costs used in our survey.

We can convert each person's estimated WTP to an implied discount rate. These estimates are presented in Table 15. The median discount rates for those with and without gas access are 12% and 10%, respectively.

VII. Prediction

In this section, we use the estimates from MM-MNL to forecast demand for water heaters across different scenarios. Table 16 shows the baseline configuration assuming no rebate in place. These values are chosen based on what is likely to be in the market during 2007-2009. Table 17 compares the forecast shares from SP data using these profiles to shares from RP data when there was no rebate. We examine three groups of respondents separately: (1) those who previously owned an electric system, with gas access; (2) those who previously owned an electric system, with no gas access; and (3) those who previously owned a nonelectric system, with gas access. The results of the first two groups are reported at the top panel and the result of the last group is reported at the bottom panel.

For RP data, the 'no rebate' situation for those who previously owned an electric system only refers to those who replaced their heater during the 2004-September 2007 period. All respondents who previously owned a nonelectric system are in a 'no rebate' situation. We report RP shares based on all observations and nonemergency cases. While conditions on nonemergency replacement should be more comparable with SP data, it significantly reduces the number of observations. For respondents who previously owned an electric water heater with gas access, both RP and SP data indicate that they are most likely to choose a gas water heater. The predicted share from SP data, however, is smaller than that of RP data. It is offset by the larger predicted share for solar and the heat pump. For respondents who previously owned an electric heater but do not have gas access, the shares of solar and heat pump are slightly higher in SP than in RP data. For those who previously owned a nonelectric heater, the predicted shares from SP data are very close to RP data, especially if we compare SP to nonemergency RP.

Overall, the predictions from SP data seem reasonable. Several factors could account for the divergences that are observed in the first two groups. First, the 'no rebate' scenario of RP comes from the earlier period when some respondents may have been unaware of the availability of solar/heat pump systems. Information conveyed about systems by stores and plumbers may not match our descriptions, designed to be an unbiased presentation of the relevant tradeoffs. Further, running cost may have been perceived (and may actually be) different than those we use in making the comparison calculations with the model based on the SP data. Finally, our DID estimates may not adequately control for all of the differences between pre and post NSW rebate periods.

Table 18 reports predictions from different rebate scenarios. The shares under the "baseline" column are from Table 17. In the first scenario, we assume that the gas system is eligible for the $300 rebate and the rebate covers 50% of the upfront cost of solar and heat pump systems. This situation mimics the NSW and Federal programs in effect during the period that our data was collected. For those who previously owned an electric system with gas access, shares of both types of gas systems are declined. Shares of solar and heat pump altogether are increased by 20%. For respondents with no gas access, the shares of solar and heat pump are added up to reflect a 38% increase. This prediction is quite similar to the DID estimate from the natural experiment where we found that the rebate program increased the share of solar and heat pumps conditional on nonemergency replacement by 24% for gas access households and 46% for no gas access households.

In the second scenario, we assume the lower amount of rebates for solar and heat pumps to cover only 25% of upfront costs while the rebate for gas remains the same at $300. This situation is similar to the new rebate program that NSW put into effect starting in early 2010 where all systems are only eligible for a $300 rebate with household still eligible for Federal rebates for solar and heat pump systems. Our model predicts that the share of gas would remain approximately the same in this case. Shares of solar/heat pump would increase by 4% and 16% for respondents with and without gas access. In the last scenario, we assume that the amount of rebates for solar and heat pumps covers only 10% of their upfront costs. This would be the case if NSW gives $300 for gas, solar and heat pumps and the Federal government stopped its rebate program. In this situation, the share of gas is predicted to rise more than that of solar/heat pump (4% vs. 1%). For households with no gas access, the shares of solar and heat pumps are predicted to increase by only 3% each. This implies that if the amount of the rebate is too low that there would be only a small overall shift toward solar and heat pump water heating systems.

The bottom panel are predictions for respondents who currently own a non-electric system. This group is ineligible for the existing NSW and Federal rebate programs. As noted earlier from RP data, most of these respondents had a gas system and replaced it with a gas system. An interesting question here is what would have happened if NSW were to implement programs like some other Australian states (*e.g.*, South Australia, Victoria, and Western Australia) where eligibility for a rebate does not require replacing an existing electric system? This change in eligibility could help shift those with gas water heaters toward purchasing solar or heat pumps. We can use our SP data to make this prediction about the impact of such policies with such a change in eligibility. The two rebate scenarios we consider are similar to those described earlier except that now we assume that there is no rebate for gas. For the first (high rebate) scenario, the shares of solar and heat pump are predicted to increase by 13% and 7%, respectively. In the second scenario, the increase of solar and heat pump share together is only 4%. In the lowest rebate scenario, the program almost has no effect on water heater demand, only increasing the share of solar by 1%.

VIII. Conclusion

In the past decade the Australian Federal government and state governments have established a wide range of financial incentives and regulations to cut greenhouse gas emissions from all sectors. This paper has focused on the hot water system, one of the major sources of carbon emissions, and the role of increasing rebates in shifting the existing stock of electric water heaters toward more climate friendly versions. Surprisingly, there is very little work that looks at the effectiveness of such programs.

We took a two pronged approach. The first was to look at recently installed water heaters using a difference-in-difference approach. Results here suggest that the NSW and other (*e.g.,* later Federal) rebates were successful at increasing the rate of switching from electric water heaters relative to the long existing baseline Federal rebate program. For households without access to natural gas, there is a clean switch to solar and heat pump systems, although the observed market share of such systems overstates the effectiveness of the new rebate programs because there was already a shift taking place toward such systems. For households with access to natural gas, there is a clear shift toward solar and heat pumps but most of these households would have installed a gas water heater rather than replaced their existing electric water heaters with another electric water heater. We also find evidence that water heater purchases under emergency situations are not nearly as responsive to the new rebate programs as water heater purchased under nonemergency situations. This suggests improving the information set available to households who make purchases in emergency situations. Previous work (Bartels, Fiebig and van Soest, 2006) points to plumbers being one of the key sources of consumer information in this situation.

Our model built on a discrete choice experiment using SP data points to considerable heterogeneity preferences toward different types of water heaters. Our results suggest considerable heterogeneity in the household discount rates which characterize the trade-off between upfront cost and the payback period related to a particular water heater, with more flexible models tending to indicate lower discount rates on average than the workhorse MNL model. Results from our discrete choice experiments using stated preference data also help isolate the effects of different rebate policies which are predicted to have sizeable effects on non-electric water heater uptake. When rebate levels are set similar to those experienced in the post-October, 2007 period, our SP model produces estimated shares similar to those observed in our RP data set. Our model also predicts substantial reductions in the market share of solar and heat pump systems installed, if rebate levels are substantially reduced toward their earlier baseline level. In addition, we predict that making households currently owning a gas system eligible for rebates if they install solar or heat pump systems would increase share of these two systems from this group who currently have gas systems by 20%.

Our two-pronged attack of using a DID approach with data from relatively recent appliance purchases taken after a major rebate program has been put in place and using a discrete choice experiment approach with stated preference data to look at a broader set of rebate options is likely to be useful in a wide array of contexts. A natural next step is to extend the analysis to other Australian states which implemented an array of different hot water system rebate programs over this time period. Combining the data and analyses across states would allow one to draw stronger and more comprehensive conclusions about the effectiveness of the rebate programs undertaken. Our approach could also be used to look at other appliance programs aimed at energy conservation involving refrigerators, space heaters and washer/dryers, as well as programs aimed at decreasing residential water use through the replacement of indoor plumbing fixtures or the conversion of outdoor landscaping.

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Figure 1: Example of information presented to respondents for solar water heater

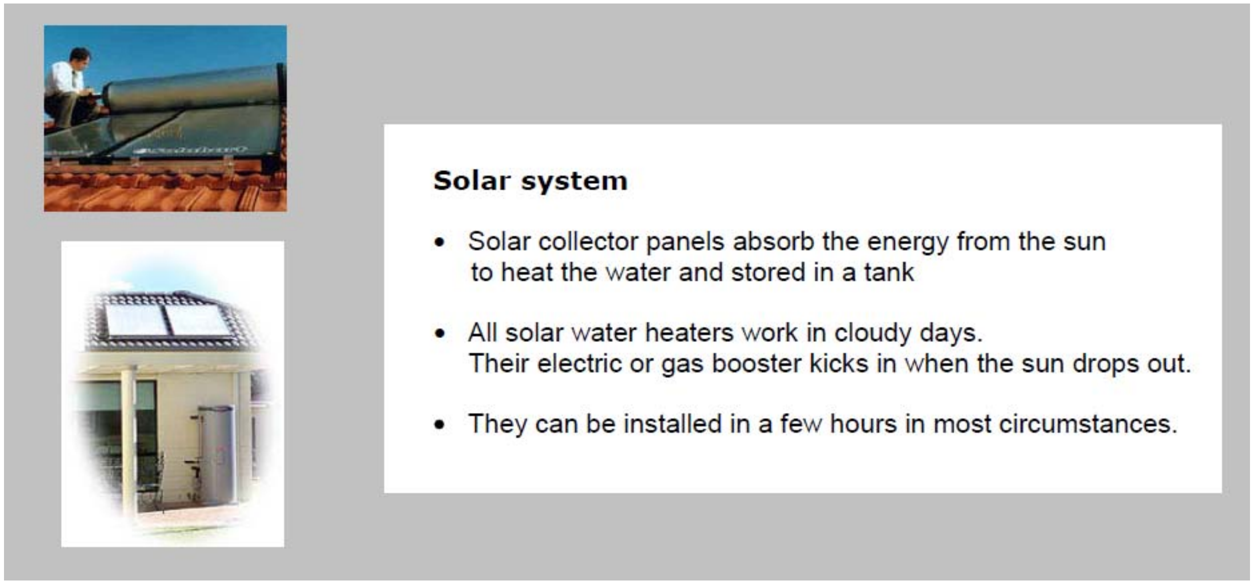

Figure 2: Example of choice scenario

	Electric Off-peak 2	Electric peak	Electric Off peak 1	Gas Storage	Gas Instantaneous	Solar	Heat Pump
Upfront cost	1500	1100	1500	1500	2100	4500	3300
Amount of mail-in rebate	-	-		-	300	-	800
Net cost	**1500**	**1100**	**1500**	**1500**	**1800**	**4500**	**2500**
Annual running costs ($/year)	**500**	**800**	**425**	**325**	**275**	**130**	**160**
Which heater is your most Preferred option?	□	□	□	□	□	□	□

Figure 3: Posterior distribution of individual-level coefficient for respondents with gas access

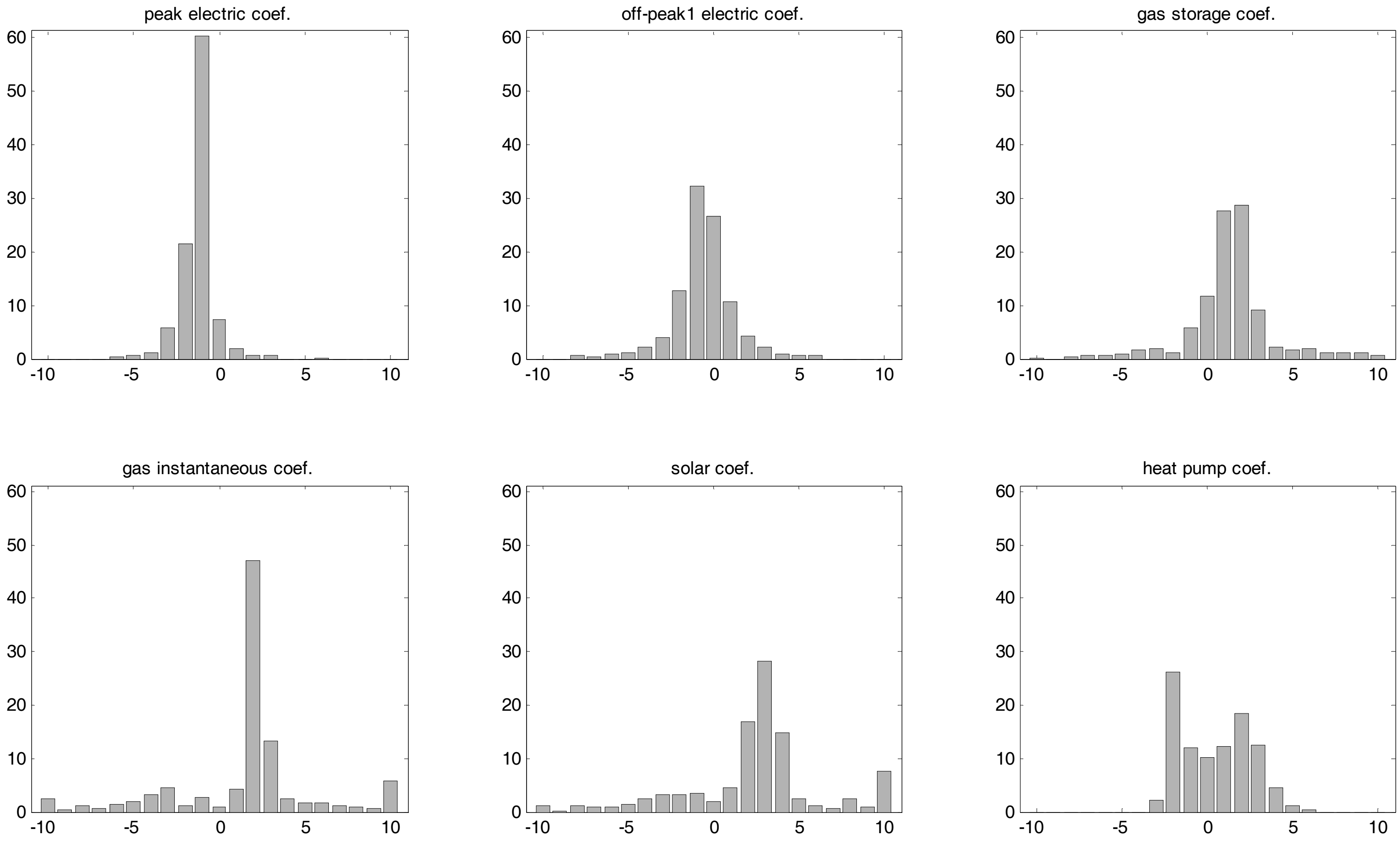

Figure 4: Posterior distribution of individual-level coefficient for respondents with no gas access

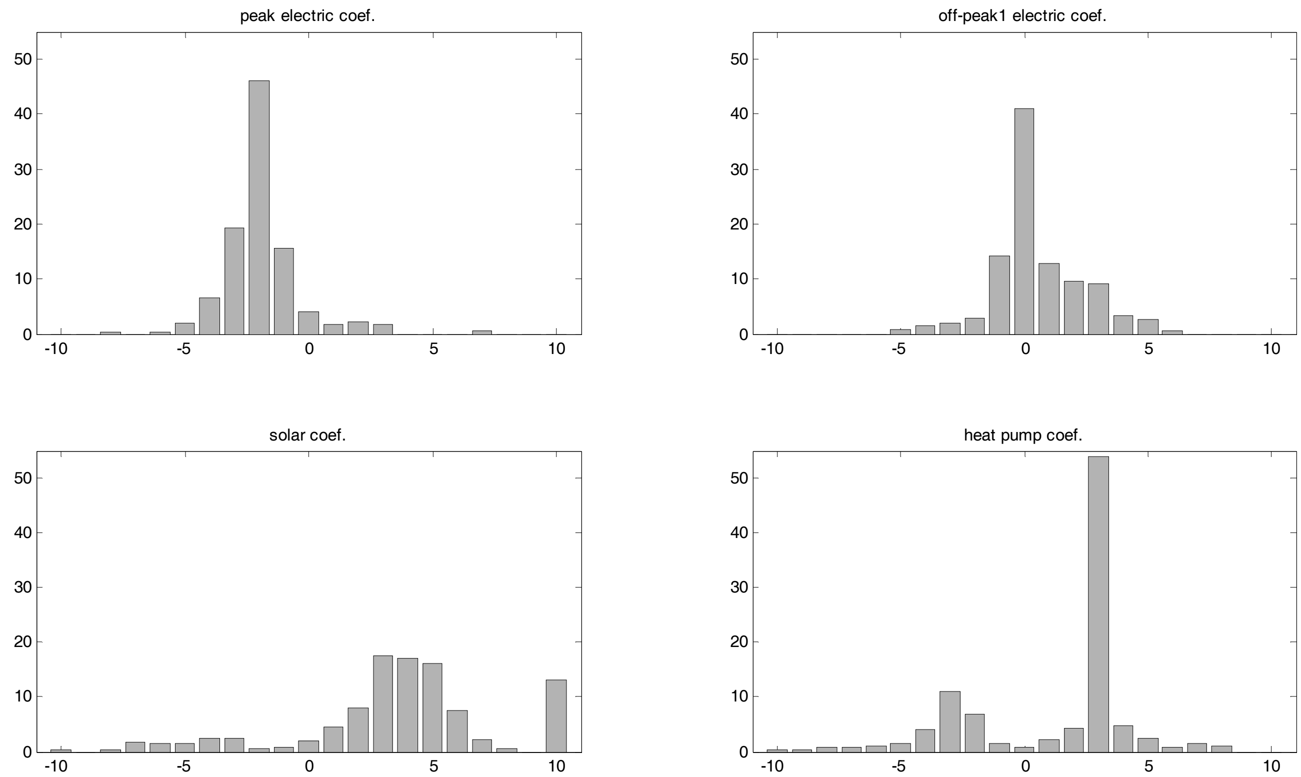

Figure 5: Posterior distribution of individual-level Willingness to Pay to save $1 on running cost annually

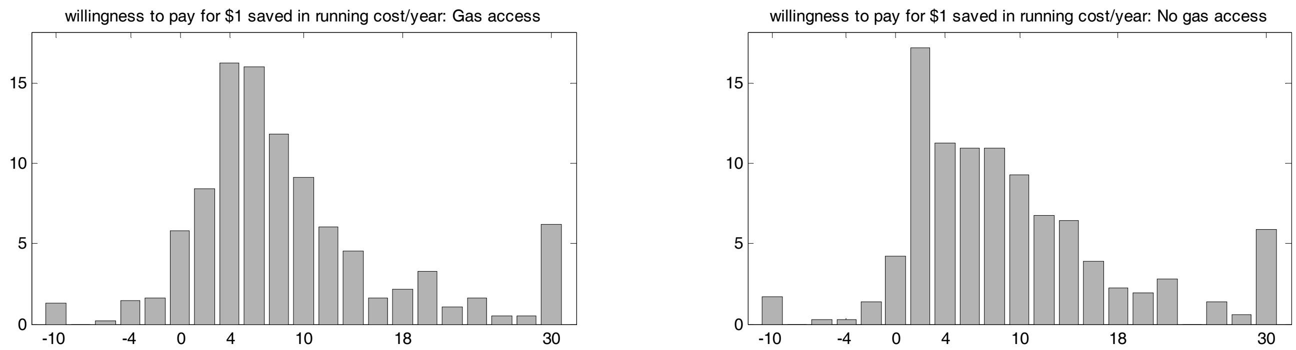

Table 1: Distribution of water heater by types in NSW households

NSW	1999	2002	2005	2008
Peak electricity	75.9	33.1	17.3	10.9
Off-peak electricity		45.9	46.5	47.1
Mains gas	20.8	23.4	25.2	25.5
Solar	2.7	2.4	1	5
Other	0.9	0.5	0.6	0.3
Did not know	0.8	2.2	8.6	12.1

Table 2: Government forecast of water heater holdings for new homes in NSW

NSW	2006-2020
Electricity	3%
Mains gas storage	30%
Mains gas instantaneous	45%
Solar	15%
Heat pump	5%
LPG	2%

Table 3: Current hot water system holding from panel survey

	Estimate age of the hot water system					
	10 or more years (1999 or earlier)		6-9 years (2000-2003)		5 years or less (2004 or later)	
	Freq	**%**	**Freq**	**%**	**Freq**	**%**
Peak electricity	172	18.6	172	19.9	222	14.5
Off-peak electricity	363	39.2	305	35.3	407	26.5
Off-peak 1	212	22.9	162	18.8	231	15.1
Off-peak 2	151	16.3	143	16.6	176	11.5
Mains gas storage	246	26.6	209	24.2	269	17.5
Mains gas instantaneous	83	9.0	123	14.3	310	20.2
Solar	46	5.0	39	4.5	190	12.4
Heat pump	2	0.2	2	0.2	108	7.0
LPG	13	1.4	13	1.5	28	1.8
Total	925		863		1534	

Table 4: Distribution of electric and nonelectric water heaters from RP and SP respondents

	RP respondents		SP respondents	
	Gas access	**No gas access**	**Gas access**	**No gas access**
Old system				
Electric system	192	472	207	321
Nonelectric system	216	32	340	33
New system				
Electric system	55	295		
Nonelectric system	353	209		
Total	408	504	547	354

Table 5: DID estimate from revealed preference data for household with gas access

	Before	After	Time difference
Previous type = electric (treatment)	2004-2007	2007-2009	
prob (elec)	0.28	0.19	-0.09
	(0.04)	(0.04)	(0.06)
prob (gas)	0.69	0.55	-0.14
	(0.04)	(0.06)	(0.07)
prob (solar/heat pump)	0.03	0.26	0.23
	(0.01)	(0.05)	(0.05)
Previous type = electric in early years (control)	2004-2005	2006-2007	
prob (elec)	0.39	0.22	-0.17
	(0.08)	(0.05)	(0.09)
prob (gas)	0.61	0.74	0.13
	(0.08)	(0.05)	(0.09)
prob (solar/heat pump)	0.00	0.04	0.04
		(0.02)	(0.02)
Effects of policy on			**DID**
prob (elec)			0.08
			(0.10)
prob (gas)			-0.27**
			(0.11)
prob (solar/heat pump)			0.19**
			(0.06)

Table 6: DID estimate from revealed preference data for household with no gas access

	Before	After	Time difference
Previous type = electric (treatment)	2004-2007	2007-2009	
prob (elec)	0.90	0.40	-0.50
	(0.02)	(0.03)	(0.04)
prob (solar/heat pump)	0.10	0.60	0.50
	(0.02)	(0.03)	(0.04)
Previous type = electric in early years (control)	2004-2005	2006-2007	
prob (elec)	0.94	0.87	-0.07
	(0.03)	(0.03)	(0.04)
prob (solar/heat pump)	0.06	0.13	0.07
	(0.03)	(0.03)	(0.04)
Effects of policy on			**DID**
prob (elec)			-0.43**
			(0.06)
prob (solar/heat pump)			0.43**
			(0.06)

Table 7: DID estimates separating emergency and nonemergency for households with gas access

Households with gas access	Nonemergency			Emergency		
	Before	**After**	**Time difference**	**Before**	**After**	**Time difference**
Previous type = electric (treatment)	2004-2007	2007-2009		2004-2007	2007-2009	
prob (elec)	0.10	0.08	-0.01	0.44	0.38	-0.06
	(0.04)	(0.04)	(0.06)	(0.06)	(0.09)	(0.11)
prob (gas)	0.87	0.59	-0.27	0.55	0.48	-0.07
	(0.05)	(0.07)	(0.08)	(0.06)	(0.09)	(0.11)
prob (solar/heat pump)	0.04	0.33	0.29	0.02	0.14	0.12
	(0.03)	(0.07)	(0.07)	(0.02)	(0.06)	(0.07)
Previous type = electric in early years (control)	2004-2005	2006-2007		2004-2005	2006-2007	
prob (elec)	0.15	0.08	-0.08	0.52	0.37	-0.14
	(0.10)	(0.04)	(0.11)	(0.10)	(0.08)	(0.13)
prob (gas)	0.85	0.87	0.03	0.48	0.59	0.11
	(0.10)	(0.05)	(0.11)	(0.10)	(0.08)	(0.13)
prob (solar/heat pump)	0.00	0.05	0.05	0.00	0.03	0.03
		(0.04)	(0.04)		(0.03)	(0.03)
Effects of policy on			**DID**			**DID**
prob (elec)			0.06			0.09
			(0.11)			(0.17)
prob (gas)			-0.30**			-0.18
			(0.14)			(0.17)
prob (solar/heat pump)			0.24**			0.09
			(0.09)			(0.08)

Table 8: DID estimates separating emergency and nonemergency for households with no gas access

No gas access	Nonemergency			Emergency		
	Before	**After**	**Time difference**	**Before**	**After**	**Time difference**
Previous type = electric (treatment)	2004-2007	2007-2009		2004-2007	2007-2009	
prob (elec)	0.74	0.15	-0.59	0.94	0.68	-0.26
	(0.07)	(0.03)	(0.08)	(0.02)	(0.04)	(0.04)
prob (solar/heat pump)	0.26	0.85	0.59	0.06	0.32	0.26
	(0.07)	(0.03)	(0.08)	(0.02)	(0.04)	(0.04)
Previous type = electric in early years (control)	2004-2005	2006-2007		2004-2005	2006-2007	
prob (elec)	0.80	0.67	-0.13	0.98	0.91	-0.07
	(0.09)	(0.11)	(0.14)	(0.02)	(0.03)	(0.03)
prob (solar/heat pump)	0.20	0.33	0.13	0.02	0.09	0.07
	(0.09)	(0.11)	(0.14)	(0.02)	(0.03)	(0.03)
Effects of policy on			**DID**			**DID**
prob (elec)			-0.46**			-0.19**
			(0.17)			(0.06)
prob (solar/heat pump)			0.46**			0.19**
			(0.17)			(0.06)

Table 9: The estimates of the increase in probability of nonemergency replacement

year	Estimates of the difference in prob. of nonemergency replacement compared to 2004	s.e.
2005	-0.09	0.07
2006	-0.09	0.07
2007 q1,q2,q3	-0.11	0.06
2007 q4,2008 q1,q2	-0.06	0.07
2008 q3,q4	-0.06	0.07
2009 q1,q2	0.20**	0.07
2009 q3, q4	0.30**	0.07

Table 10: Suggested sizes of water heaters for different water usage level

Suggested tank size/flow rate	Small usage	Medium usage	Large usage
Electric (storage – peak)	50-80 L	125,160 L	250,315 L
Electric (storage – off-peak 1,2)	160-250 L	250, 315 L	315,400 L
Gas (instantaneous)	16-20 L/min	20,24,26 L/min	26,32 L/min
Gas (storage)	90-130 L	135,160 L	160, 200 L
Solar	180-300 L + 1 panel	300-370 L + 2 panels	400-440 L + 3 panels
Heat pump	160-250 L	270-310 L	300-340

Table 11: Summary of model assumption on distribution of taste heterogeneity

MNL	$\beta_n = \beta \quad \forall\, n$
Latent class	$\beta_n = \beta_s$ with probability $w_{n,s}$ where $\sum_s w_{n,s} = 1$ and $w_{n,s} > 0\ \forall\, s$
Mixed logit	$\beta_n \sim MVN(\beta, \Sigma)$; or $\beta_n = \beta + \eta_n$ where $\eta_n \sim MVN(0, \Sigma)$
G-MNL	$\beta_n = \sigma_n \beta + \gamma\eta_n + (1-\gamma)\sigma_n\eta_n$ where $\eta_n \sim MVN(0, \Sigma)$
MM-MNL	$\beta_n \sim MVN(\beta_s, \Sigma_s)$ with probability $w_{n,s}$ where $\sum_s w_{n,s} = 1$ and $w_{n,s} > 0\ \forall\, s$

Table 12: Choice frequency from stated experiment data

	Gas access		**No gas access**	
	Freq.	**%**	**Freq.**	**%**
Electric - peak	215	2	152	3
Electric - off-peak				
off-peak 1	514	6	830	15
off-peak 2	214	2	275	5
Gas - storage	1353	15		
Gas - instant	1808	21		
Solar	3071	35	2732	48
Heat pump	1577	18	1675	30
No of scenarios	8752		5664	
No of respondents	547		354	

Table 13: Selected results for respondents with gas access

	MNL	Latent class						MIXL (correlated)	G-MNL (correlated)	Mixture-of-normals (2 indep.normals)	
		class 1	class 2	class 3	class 4	class 5	class 6			class 1	class 2
Mean											
(omitted electric off-peak2)											
Electric peak	0.44**	-0.44	-30	2.14	0.81**	-30	12.52	-2.81**	1.12**	-1.13**	-1.35**
	(0.10)	(0.40)	-	(1.62)	(0.09)	-	-	(0.28)	(0.28)	(0.26)	(0.28)
Electric off-peak 1	0.41**	0.92**	-0.15	0.41	1.12**	-2.53**	10.94	-0.54**	1.7**	-0.02	-1.07**
	(0.08)	(0.20)	(0.14)	(1.09)	(0.06)	(0.18)	-	(0.14)	(0.30)	(0.21)	(0.18)
Gas storage	1.38**	3.21**	0.1	-0.1	0.54**	-1.54**	13.82	1.83**	5.64**	1.69**	0.9**
	(0.08)	(0.19)	(0.16)	(1.27)	(0.11)	(0.14)	-	(0.18)	(0.31)	(0.16)	(0.28)
Gas instantaneous	1.73**	2.59**	1.35**	-0.01	0.004	-0.26*	16.06	2.26**	6.59**	2.26**	1.03**
	(0.08)	(0.21)	(0.15)	(1.27)	(0.16)	(0.16)	-	(0.20)	(0.34)	(0.17)	(0.31)
Solar	2.5**	2.86**	2.01**	3.91**	0.9**	0.26	11.81	3.12**	7.25**	2.76**	1.23**
	(0.10)	(0.22)	(0.19)	(1.25)	(0.16)	(0.21)	-	(0.23)	(0.36)	(0.19)	(0.37)
Heat pump	1.69**	1.89**	2.21**	2.64**	-0.18	-4.73**	12.66	1.3**	5.32**	1.56**	-1.71**
	(0.10)	(0.22)	(0.20)	(1.25)	(0.19)	(0.44)	(0.00)	(0.24)	(0.34)	(0.20)	(0.34)
Cost-after-rebate/10000	-8.62**	-18.96**	-17.03**	-5.73**	-13.92**	-11.38**	-7.74**	-22.81**	-26.57**	-27.3**	-16.93**
	(0.18)	(0.50)	(0.44)	(0.36)	(0.55)	(0.56)	(1.11)	(0.59)	(1.02)	(0.80)	(1.01)
1 if mail-in rebate dummy	0.002	-0.06	0.25**	-0.003	-0.29**	0.06	-0.03	-0.04	0.03	0.01	-0.28*
	(0.03)	(0.08)	(0.08)	(0.09)	(0.12)	(0.14)	(0.16)	(0.05)	(0.05)	(0.06)	(0.16)
Annual running cost/1000	-3.99**	-5.69**	-13.12**	-7.5**	-1.77**	-11.29**	-7.07**	-16.33**	-17.94**	-22.02**	-9.35**
	(0.20)	(0.34)	(0.54)	(0.88)	(0.32)	(0.66)	(1.46)	(0.57)	(0.72)	(0.76)	(0.74)
Covariance	No	no						yes	yes	yes	yes
class prob.		0.34**	0.21**	0.15**	0.14**	0.09**	0.06**			0.66	0.34
		(0.03)	(0.02)	(0.02)	(0.02)	(0.01)	(0.02)			(0.02)	(0.02)
τ									0.57**		
									(0.02)		
γ*									0.03		
									(0.13)		
No. of parameters	9	59						54	56	37	
Loglikelihood	-12861	-8924						-7447	-7198	-7142	
AIC	25740	17967						14933	14508	**14359**	
BIC	25804	18384						15075	14904	**14620**	
CAIC	25813	18443						15095	14960	**14657**	

Table 14: Selected results for respondents with no gas access

	MNL	Latent class						MIXL (correlated)	G-MNL (correlated)	Mixture-of-normals (2 indep. Normals)	
		class 1	class 2	class 3	class 4	class 5	class 6			class 1	class 2
Mean											
(omitted electric off-peak2)											
Electric peak	-0.04	0.86	0.13	16.08	0.7**	-0.41	-2.58**	-0.7**	0.03	-1.84**	-1.63**
	(0.11)	(0.55)	(0.31)	-	(0.16)	(0.41)	(0.59)	(0.25)	(0.27)	(0.68)	(0.35)
Electric off-peak 1	0.61**	-1.77**	1.65**	16.57	1.57**	0.03	-4.23**	0.16	0.55*	0.62*	0.31
	(0.08)	(0.73)	(0.21)	-	(0.11)	(0.22)	(0.49)	(0.21)	(0.29)	(0.33)	(0.23)
Solar	1.84**	1.88**	2.4**	21.27	1.28**	0.24	-5.03**	2.89**	3.84**	3.9**	3.33**
	(0.12)	(0.48)	(0.36)	-	(0.23)	(0.52)	(1.26)	(0.24)	(0.48)	(0.41)	(0.44)
Heat pump	1.23**	1.22**	1.95**	17.63	-0.33	2.13**	-5.39**	1.8**	2.47**	3.1**	-1.21**
	(0.12)	(0.48)	(0.36)	-	(0.33)	(0.43)	(1.02)	(0.23)	(0.44)	(0.40)	(0.52)
Cost-after-rebate/10000	-7.13**	-16.21**	-23.23**	-5.99**	-12.9**	-4.65**	-15.04**	-22.43**	-26.29**	-29.48**	-15.86**
	(0.21)	(0.71)	(0.93)	(1.09)	(0.62)	(0.67)	(1.10)	(1.04)	(1.40)	(1.45)	(1.22)
1 if mail-in rebate	0.05	0.19	-0.14	0.26	-0.18	0.32	0.77	-0.06	-0.06	-0.05	0.34
	(0.05)	(0.13)	(0.17)	(0.23)	(0.20)	(0.26)	(1.00)	(0.11)	(0.14)	(0.14)	(0.22)
Annual running cost/1000	-4.6**	-21.68**	-10.95**	-1.19	-2.81**	-3.87**	-13.52**	-19.35**	-23.31**	-27.45**	-4.96**
	(0.29)	(1.36)	(1.01)	(1.94)	(0.58)	(1.03)	(1.74)	(0.88)	(1.31)	(1.80)	(0.94)
Covariance	no	no						yes	yes	yes	yes
class prob.		0.33**	0.20**	0.18**	0.13**	0.12**	0.04**			0.58**	0.42**
		(0.03)	(0.02)	(0.03)	(0.02)	(0.02)	(0.01)			(0.03)	(0.03)
τ									0.4**		
									(0.04)		
γ^*									-5		
									(8.01)		
No. of parameters	7	47						35	37	29	
Loglikelihood	-6250	-3937						-3511	-3478	**-3441**	
AIC	12514	7967						7092	7029	6941	
BIC	12560	8279						7325	7275	7133	
CAIC	12567	8326						7360	7312	7162	

Table 15: Distribution of estimated discount rates

Discount rates	Gas access Freq (%)	No gas access Freq (%)
Less than 2%	22	26
2-10%	22	23
10-20%	24	18
20-40%	16	10
Higher than 40%	15	23
Median discount rate	12%	10%

Table 16: Baseline configuration

	Small		Medium		Large	
	net upfront cost	running cost	net upfront cost	running cost	net upfront cost	running cost
Electric						
Peak	900	350	1100	600	1400	875
Off peak 1	1200	180	1500	325	1800	450
Off peak 2	1200	300	1500	500	1800	750
Gas						
Storage	1200	180	1500	325	1800	450
Instantaneous	1600	140	2000	225	2400	300
Solar/Heat pump						
Solar	4500	130	5500	210	6500	320
Heat pump	4000	130	5000	210	6000	320

Table 17: Prediction with no rebate

A. Previously own electric system	Gas Access			No gas access		
	Choices share from RP data ("before policy")		Predicted shares SP data	Choices share from RP data ("before policy")		Predicted shares SP data
	All	Nonemergency		All	Nonemergency	
Electric						
Peak	0.10	0.08	0.05	0.23	0.13	0.06
Off peak	0.19	0.02	0.22	0.68	0.61	0.62
Gas						
Storage	0.15	0.12	0.18			
Instantaneous	0.54	0.75	0.44			
Solar/Heat pump						
Solar	0.03	0.04	0.09	0.08	0.18	0.20
Heat pump	0.00	0.00	0.03	0.02	0.08	0.12
No of obs.	114	52		189	38	

B. Previously own nonelectric system	Gas Access		
	Choices share from RP data ("before policy")		Predicted shares SP data
	All	Nonemergency	
Electric			
Peak	0.01	0.00	0.02
Off peak	0.03	0.04	0.06
Gas			
Storage	0.55	0.34	0.30
Instantaneous	0.38	0.55	0.50
Solar/Heat pump			
Solar	0.04	0.07	0.09
Heat pump	0.00	0.01	0.02
No of obs.	216	71	

Table 18: Counterfactual policy experiment from SP data

A. Previously own electric system

	Gas Access				No gas access			
Rebate	Baseline	Scenario I	Scenario II	Scenario III	Baseline	Scenario I	Scenario II	Scenario II
gas	-	$300	$300	$300	-	$300	$300	$300
solar/heat pump	-	covering 50% of upfront cost	covering 25% of upfront cost	covering 10% of upfront cost	-	covering 50% of upfront cost	covering 25% of upfront cost	covering 10% of upfront cost
Electric								
Peak	0.05	0.04	0.04	0.04	0.06	0.04	0.05	0.06
Off peak	0.22	0.14	0.17	0.17	0.62	0.26	0.47	0.58
Gas								
Storage	0.18	0.16	0.19	0.20				
Instantaneous	0.44	0.35	0.43	0.46				
Solar/Heat pump								
Solar	0.09	0.20	0.11	0.09	0.20	0.41	0.28	0.23
Heat pump	0.03	0.12	0.05	0.04	0.12	0.29	0.20	0.15

B. Previously own nonelectric system

	Gas Access			
Rebate	Baseline	Scenario I*	Scenario II*	Scenario III*
gas	-	-	-	-
solar/heat pump	-	covering 50% of upfront cost	covering 25% of upfront cost	covering 10% of upfront cost
Electric				
Peak	0.02	0.02	0.02	0.02
Off peak	0.06	0.05	0.06	0.06
Gas				
Storage	0.30	0.25	0.29	0.30
Instantaneous	0.50	0.38	0.47	0.50
Solar/Heat pump				
Solar	0.09	0.22	0.12	0.10
Heat pump	0.02	0.09	0.03	0.02

Appendix

Table A1: DCE Attributes and Levels

	Net cost (after rebate)				Mail-in rebate				Annual running costs			
	Level 1	Level 2	Level 3	Level4	Level 1	Level 2	Level 3	Level 4	Level 1	Level 2	Level 3	Level 4
Small water usage												
Electric (off-peak 2)	1200				0				300			
Electric (peak)	600	800	1000	1200	0	0	0	0	350	450	550	650
Electric (off-peak 1)	800	1050	1300	1550	0	0	0	0	180	220	260	280
Gas storage	800	1050	1300	1550	0	250	450	650	180	220	260	280
Gas instantaneous	1200	1465	1730	2000	0	250	450	650	140	180	220	260
Solar	1200	2000	2800	3600	0	1500	2000	2500	70	90	110	130
Heat pump	1200	2000	2800	3600	0	1500	2000	2500	70	90	110	130
Medium water usage												
Electric (off-peak 2)	1500				0				500			
Electric (peak)	900	1100	1300	1500	0	0	0	0	500	650	800	950
Electric (off-peak 1)	1050	1350	1650	1950	0	0	0	0	325	375	425	475
Gas storage	1050	1350	1650	1950	0	250	450	650	325	375	425	475
Gas instantaneous	1500	1830	2160	2500	0	250	450	650	225	275	325	375
Solar	1500	2500	3500	4500	0	1500	2000	2500	100	130	160	210
Heat pump	1500	2500	3500	4500	0	1500	2000	2500	100	130	160	210
Large water usage												
Electric (off-peak 2)	1800				0				750			
Electric (peak)	1200	1400	1600	1800	0	0	0	0	750	950	1150	1350
Electric (off-peak 1)	1300	1650	2000	2350	0	0	0	0	450	525	600	675
Gas storage	1300	1650	2000	2350	0	250	450	650	450	525	600	675
Gas instantaneous	1800	2200	2600	3000	0	250	450	650	300	375	450	525
Solar	1800	3000	4200	5400	0	1500	2000	2500	200	240	280	320
Heat pump	1800	3000	4200	5400	0	1500	2000	2500	200	240	280	320