Evaporative Cooler Rebate Program Cuts Load Significantly, and May Overcome Class Barrier

Adrienne Vayssières Kandel, California Energy Commission, Sacramento, CA*

ABSTRACT

An application of the new instrumented decomposition method shows that an evaporative cooling rebate program worked far better than previously thought, in hot dry areas of Southern California. Savings reached an eighth of pre-program electricity load, as program-induced buyers cut their air conditioning usage by two thirds. Free ridership was low, around 20%. Even lower free ridership rates for higher income levels suggest that the program may have helped overcome a social barrier to evaporative cooler adoption: its low-class "swamp cooler" image. These findings are supported by reasonably small confidence intervals and low sensitivity to variable choice.

Introduction

In 1994 Southern California Edison (SCE) gave partial rebates to hundreds of customers outside the coastal climate zone who purchased new evaporative coolers to supplement their central air conditioning. SCE hoped that customers would replace much of their air conditioning with evaporative cooling, thus lowering electricity use significantly on hot days, when electricity is most valuable. This paper summarizes findings about the program's effectiveness in a question/answer format, based on application of the author's instrumented decomposition (ID) method, presented in Kandel (1999b) in these proceedings, and detailed in Kandel (1999a). After overviewing the *Method of Estimation*, the *Potential for Self-Selection Bias* and the *Data Set*, this paper addresses the following *Questions*:

- Is the decision to participate simultaneous with the decision to have evaporative cooling?
- How much free ridership is present? With what accuracy is it predicted?
- Historically, evaporative cooling has been seen as a lower-class technology, making people reluctant to buy it. Has the program succeeded in lowering this social barrier?
- How much electricity did the evaporative cooling systems save?

The paper ends with *Conclusions* and an *Appendix: the Regression Results.*

Method of Estimation

ID is a two-stage method to estimate net energy savings due to appliance rebate programs and other single-item incentives or promotions. ID is based on a decomposition of energy bill changes into *appliance savings* due to the rebated item and *trend savings* due to the general economy, weather, social climate and so on. Like many other estimation methods, it requires a sample of program participants and a comparison sample of nonparticipants.

In ID's first stage, a 3-choice nested logit regression predicts households choices between not having evaporative cooling, having evaporative cooling as a program nonparticipant, or having evaporative cooling as a program participant. The nested logit formulation allows for decisions to have the cooling system to influence the decision to participate, and vice-versa. The branching structure, which is *not* the assumed decision order is

Top Branch: *have evaporative cooling or not,* Bottom Nest: *for those with evaporative cooling, participate or not in the program.*

Next, the probability of *natural ownership*, i.e., of having the appliance in the absence of the rebate program, is predicted using nested logit regression results. The probability of natural ownership is the probability of ownership given nonparticipation. By Bayes' Law, that is the probability of ownership and nonparticipation divided by the probability of nonparticipation. Train et al. (1994) introduced this method, for estimating free ridership.

In the second stage, energy savings are regressed on independent variables that include interaction terms for predicted probability of natural ownership, and participation or predicted probability of participation, based on the first-stage regression. Using these interaction terms, the second-stage equation can break total energy savings into four components: trend savings, nonparticipant buyers' appliance savings, free riders' appliance savings, and program-induced buyers' appliance savings (net savings). Letting *b* represent natural ownership and *P* represent participation, the basic equation of savings is

total savings = trend savings + (1-P)(b)(nonparticipant owners' appliance savings)
+ (P)(b)(free riders' appliance savings)
+ (P)(1-b)(program-induced buyers' appliance savings).

Potential for Self-Selection Bias

ID was developed to estimate net savings consistently, without self-selection bias. Self-selection bias occurs when participants have naturally different energy savings behavior than nonparticipants, so that inherent differences between the participant and the comparison groups can be mistaken for effects of the program. Bias can appear when participants and nonparticipants have different propensities to naturally own the program-targeted appliance, when they have different savings response to getting the appliance, or when they have different trend savings unrelated to the appliance. The "fully instrumented" version of ID, which uses predicted probability of participation in place of *P* in the second stage regression, treats all three potential biases. The "singly instrumented" version uses actual participation instead, and treats only the former two types of bias; vulnerable to self-selection in trend savings. (Both versions used predicted natural ownership in place of *b*.)

Unfortunately, the fully instrumented version requires that the population (not just the sample) contain a substantive proportion of participants, or the model will becomes too imprecise because predicted probability of participation will vary little from zero. For the SCE evaporative cooling rebate program, fewer than 0.1% of electricity customer households were participants. Hence, it was necessary to use the singly instrumented version of ID, and estimates presented herein may be subject to self-selection bias in trend savings.

Still, such bias if it exists should be small. Most self-selection bias will come from differing natural ownership propensities between participants and nonparticipants, or from participants having more (or less) potential to save from the appliance. Participants are likely to have different energy use *levels* than nonparticipants, if they come from different socioeconomic groups, but that will not translate into different appliance-unrelated *changes* in energy use from one year to the next. Such differences in trend savings would have to come from some factor that affected both trend savings and the participation decision significantly, and which was unrecorded in the data so that the second-stage regression could not control for it. The most likely such factors would normally be remodeling or making additions to the home, but in this case the data set included a variable for building additions, and some variables related to remodeling.

The Data Set

The study uses mail survey responses from SCE's 1995 Residential Appliance Saturation Survey (RASS), merged with electricity billing records. RASS was sent to a stratified random sample of general population households, and to all program participants. For my analysis I eliminated ten influential outlying observations whose energy use changed more than 20 kWh/day. This left 3457 observations for the first-stage nested logit regression, including 476 evaporative cooling rebate program participants. For the second-stage savings regression I excluded 562 air conditioning rebate participants to avoid confounding the effects of the two rebate programs.

Since the RASS questionnaire was designed for electricity demand forecasting rather than program evaluation, it asked people whether they had evaporative cooling but not when they obtained it. Nonparticipant owners can be identified in the data, but nonparticipant program-year buyers cannot. Therefore, the nested logit regression predicts ownership rather than purchase of the evaporative cooling system (this is one variation of the ID method).

Questions

Is the decision to participate simultaneous with the decision to have evaporative cooling?

The inclusive value parameter from the nested logit regression, "λ," was 0.68, suggesting that a large part of the participation decision was simultaneous with the decision to have evaporative cooling. This means that the program could well have influenced that decision, as was its intention. λ=0 would mean a totally sequential decision (first households decided they wanted evaporative cooling, and second they enrolled in for the program to get a rebate). λ=1 would mean total simultaneity.

How much free ridership is present? With what accuracy is it predicted?

"Free riders" are participants who would own evaporative cooling by the end of the program period, even without the rebate. The nested logit model predicts the free ridership rate as 18.5%, with a standard error of 1.6%.

That standard error is deceptively low, however, obtained on the assumption that the model has been correctly specified. An analysis of the sensitivity of estimated free ridership to change in the model specification is needed.

I chose a radical test of model sensitivity: I reran the model twice, each time with half of the variables included and the complementary half excluded. The two halves were chosen arbitrarily (numbering variables from first to last, one model had the even numbered variables, the other the odd). One of these under-specified models yielded a free ridership rate of 28% while the other yielded 9%.

With sensitivity to variables considered, then, one can assert that free ridership ranges from about 10 to 30%, and the best point estimate is 18.5%.

Historically, evaporative cooling has been seen as a lower class technology, making people reluctant to buy it. Has the program succeeded in lowering this social barrier?

Results in the participation branch of the nested logit regression suggest that the program had some success since newer and wealthier homes participate more. This could reflect program success at targeting upscale homes, and portend a change in attitudes. Alternatively, it could mean that among people who choose evaporative cooling, the wealthier ones with the newer homes are naturally most likely to participate in this SCE program.

Wealthier individuals in newer homes could be most likely to participate for several reasons. First, they are more likely to have central air conditioning, a stated condition of the program. Second, higher income individuals may be more apt to inform themselves about SCE programs. Third, SCE conducted a separate evaporative cooling subsidy program for qualifying low income houses. Fourth, lower income, older homes may be closer to saturation with evaporative cooling technology. Finally, SCE may have been successful in recruiting higher income homes to overcome the "low-class" image that discourages the adoption of evaporative cooling systems.

The successful recruiting view is supported by a moderately high inclusive value coefficient and a fairly low free ridership rate. Taken together, these suggest most participant households decided to obtain evaporative cooling concurrently with and because of their program participation.

Moreover, free ridership rates appear to fall with income class, at least until the very high $100,000 level income range is reached (Table 1). Essentially, the wealthier a participant household is, the less likely it would have evaporative cooling without the program. Therefore it is unlikely that wealthy households took advantage of the program to finance an installation they had already decided upon. Instead, most wealthy households would not have chosen to own evaporative cooling without program exposure, even though they generally could afford it.

At the least, this confirms that the SCE program was able to overcome the class or ignorance barrier to evaporative cooling ownership for a large number of middle to upper middle income families. Since wealthier households are probably less sensitive to the effect of the $125 rebate on price than poorer households, this result also suggests that they are responding to other aspects of the program such as its promotion of evaporative cooling as an energy-savings supplement to central air conditioning. Such a view contradicts the low-class image of evaporative cooling as a cheap technology designed for people who cannot afford central air conditioning. As the program causes evaporative coolers to be seen more on higher-income homes, the low-class image may be further weakened.

Table 1. Free ridership declines with income until $100,000. The approximate standard error is the full regression standard error of 1.6%, adjusted for sample size (multiplied by the square root of 476 over sample size).

Free Ridership Rates by Income Level of Participants			
Household Income	**Free Ridership Rate**	**Approximate Standard Error**	**Sample Size**
25,000 and below	22.7%	3.4%	104
25,001 to 50,000	17.2%	2.3%	234
50,001 to 75,000	16.9%	3.6%	93
75,001 to 100,000	11.7%	6.3%	30
100,000 and above	17.5%	9.0%	15
All homes	***18.5%***	***1.6%***	***476***

How much electricity did the evaporative cooling systems save?

The ID model estimates net savings to average 2.77 kWh/day per participant over the year, close to 12% of pre-program electricity use. That comes to 3.40 kWh/day per net saver (participant who is not a free rider), with a standard error of 0.40 kWh/day, and a 95% confidence interval extending from 2.6 to 4.2 kWh/day. A "sensitivity interval" ranges from 2.4 to 4.2 kWh/day, based on two opposite under-specified models, using complementary halves of the full set of independent variables, without full correction for sampling distortions. The sensitivity interval's boundaries should be viewed as unlikely extremes, analogous to a confidence interval.

Pre-program engineering estimates placed participants' air conditioning electricity use at an average 4.95 kWh/day (Xenergy, 1996, p. 2-27). By that estimate and ID results, net savers reduced their air conditioning usage by 69%.

How do ID estimates compare to other estimates of the same program's impact?

While SCE generously provided me with data, they wish it made clear that they have neither studied nor sanctioned my results. SCE developed engineering predictions, which their program evaluator Xenergy used in a statistically-adjusted engineering (SAE) model. Xenergy multiplied the result by a free ridership ratio of 46%, based on a sequentially estimated nested logit regression (Xenergy, 1996).

Table 2 Comparison of net savings estimates using various estimation methods

Gross Savings Estimates per Participant (kWh/day)	
Statistically Adjusted Engineering Model (Xenergy)	1.2
Simple Difference in Differences	2.2
Instrumented Decomposition: appliance-related savings of average participant	3.0
Instrumented Decomposition: appliance-related savings of average net saver (free riders' device savings not averaged in)	3.4
Engineering Prediction (SCE)	3.4
Net Savings Estimates per Participant (kWh/day)	
Statistically Adjusted Engineering estimate times Xenergy's net-to-gross ratio of 54%	0.6
Statistically Adjusted Engineering estimate times the net-to-gross ratio of 81.5% estimated for first stage of ID	1.0
Difference in Differences times net-to-gross ratio of 81.5%	1.8
Instrumented Decomposition	2.8

Table 2 compares ID estimates (shaded) to SCE's results, as well as classic difference in differences methods. ID results match the engineering predictions and are much higher than the SAE estimates.

I believe Xenergy's results understate net savings substantially for two reasons: First, SAE results are model-dependent, and Eto and Sonnenblick (1995) have found that they tend to underestimate total savings. Second, their free ridership estimate is too high because it was estimated for Palm Springs only, the SCE territory with the highest natural ownership rate for evaporative coolers. In addition, sequential nested logit estimation led to high variance; my estimate used the efficient simultaneous estimation method.

The simple difference in differences gross savings estimate is about 40% too low because it assumes participants and nonparticipants have the same natural savings on average. ID results show that during the program period nonparticipants increased their trend energy use (unrelated to evaporative cooling) by about 0.8 kWh/day, while participants naturally increased theirs by as much as 1.4 kWh a day. A difference in differences wrongly takes that 0.6 kWh/day difference as a negative component of the participation effect.

Conclusions

The rebate program was highly successful at saving electricity, as people turned them on enough to reduce air conditioning usage by two thirds, during Southern California deserts' hot, dry summer. It also recruited many higher income families, and appeared to lower the class barrier to evaporative cooling. It would be useful to conduct participant interviews to see whether it was the $125 or the SCE promotion campaign (or both) that sold wealthier families on evaporative cooling.

Appendix: The Regression Results

Tables 3 and 4 show regression results from ID, with possibly significant effects in bold print. Stratification variables are used as regressors to control for the sampling plan. The nested logit regression had a pseudo-R^2 of .35.

Table 3 Stage I Nested Logit Regression

VARIABLE	COEFFICIENT	"p" VALUE (two-tailed)
Stage I "Bottom" Nest: Probability of Participation given Ownership		
intercept	**-11.0**	**0.0000**
ELEC94 (kWh/day used in 1994)/ 22.2495	**4.23**	**0.03**
ELECSQ (ELEC94 squared)/ 990,805,100	**-7.70**	**0.04**
Central Valley	**-0.814**	**0.001**
Inland	**1.23**	**0.0000**
Single Family Home	**1.00**	**0.04**
AGEHOME (deviation from average home age based on interval responses)/29.25	-0.713	0.23
AGEHOM2 (AGEHOME squared) / 1711.125	0.519	0.45
Owner Rather Than Renter	**1.06**	**0.005**
Wood Is Main Heating System	**0.405**	**0.04**
In Regions With Many Participants	**1.14**	**0.0004**
In Regions With Few Participants	**-1.22**	**0.0000**
Self-Reports Having Central Air	**3.45**	**0.0000**
DEVKSQFT (deviation from average home square footage based on interval responses) / 1000. Zero for item nonrespondents.	**-0.401**	**0.01**
NOSQFT (nonrespondent to square footage question)	0.0200	0.95
RETIRED	**0.543**	**0.0035**
INCOME (Annual income based on interval responses) / 55,000	**1.87**	**0.006**
INCOME2 (INCOME squared) / 6050	**-1.43**	**0.03**
Stage I "Top" Branch: Probability of Ownership		
intercept	**-8.91**	**0.0000**
ELEC94	**2.94**	**0.02**
ELECSQ	**-4.52**	**0.07**
Central Valley	0.119	0.47
INLAND	-0.0687	0.65
House	**2.04**	**0.0000**
Mobile Home	**3.03**	**0.0000**
AGEHOME	**0.758**	**0.035**
AGEHOM2	**-0.711**	**0.1**
Owner Rather Than Renter	**0.586**	**0.02**
Wood Is Main Heating System	**0.266**	**0.02**
INCOME	**-0.811**	**0.0000**
In Districts with Much Evap. Cooling	**2.40**	**0.0000**
BEDROOM (Number of bedrooms)/6	-0.479	0.12
Inclusive Value Parameter	**0.682**	**0.0000**

Table 4 Stage II Savings Regression: Electricity Savings (kWh/day)

VARIABLE	COEFFICIENT	"p" VALUE (two-tailed)
TREND SAVINGS COMPONENTS		
trend savings intercept	-0.151	0.6
ELEC94	**-3.11**	**0.09**
ELECSQ	1.07	0.80
Central Valley	-0.153	0.52
Inland	0.0167	0.92
Single Family Home	0.0008	0.996
AGEHOME	**0.344**	**0.03**
Number of Inhabitants Increased	**-0.767**	**0.0000**
Number of Inhabitants Decreased	**1.32**	**0.0000**
Disposed of a Refrigerator or Freezer	**0.901**	**0.01**
Replaced a Refrigerator or Freezer	0.585	0.15
Number of Misc. Appliances Replaced	0.175	0.14
Has a private pool or spa	**-4.33**	**0.0001**
Newly obtained central a/c	-0.399	0.67
Replaced older central a/c	0.288	0.66
Had maintenance on HVAC equipment	0.107	0.51
Square ft. added to home (in hundreds)	**-0.873**	**0.0000**
CDD70 Change in cooling degree days (base 70) post- minus pre-program	**-1.50**	**0.0000**
NONPARTICIPANT OWNER APPLIANCE SAVINGS COMPONENTS		
nonparticipant owner intercept	-0.0396	0.97
ELEC94	**6.54**	**0.007**
Central Valley	**-0.953**	**0.07**
Inland	0.871	0.42
Single Family Home	-0.259	0.76
AGEHOME	**-0.723**	**0.10**
Reports Rarely Cooling the Home	2.30	0.31
Reports Cooling When Someone Feels Hot	**-2.51**	**0.09**
This is a Winter Home	**-2.62**	**0.05**
Long-time Resident	**0.787**	**0.05**
Window-related Conservation Measures	**-0.692**	**0.01**
Self-reports Central a/c	-0.0329	0.98
PARTICIPANT APPLIANCE SAVINGS COMPONENTS		
free rider intercept	-1.02	0.63
net saver intercept	1.04	0.60
ELEC94	**4.70**	**0.0025**
Central Valley	0.64	0.42
Inland	0.198	0.75
Single Family Home	-0.104	0.94
AGEHOME	**-1.34**	**0.01**
Newly obtained central a/c	**-3.69**	**0.04**
New Resident	**8.51**	**0.0000**
Months home was vacant before program	**-0.399**	**0.095**
Number of various fan types in home	**0.544**	**0.096**
Has a private pool or spa	**-5.38**	**0.04**
Self-reports Central a/c	0.39	0.71

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