Are Energy Audits Worth It? Teasing Apart the Role of Audits in Driving Customer Efficiency Actions

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Historically, audit programs have existed alongside efficiency programs. Their primary role has been to educate customers on the availability of energy-saving actions and rebate programs and induce adoption of energy-saving actions. In order to gauge the effectiveness of audits, evaluators have worked to separate out the independent effects of audit programs in inducing energy and demand savings, both in terms of motivating customers to adopt outside rebate programs and in driving program participation. This paper uses program tracking system records and telephone survey data collected from audit and rebate program participants and nonparticipants to tease apart causal relationships between customers' predisposition to seek energy conservation improvements and the effectiveness of audits at inducing conservation actions.

INTRODUCTION

PG&E's Agricultural Energy Management Services (EMS), an energy audit and pump test program, is designed to inform agricultural customers of no- and low-cost actions that could be implemented as well as capital improvements that could be undertaken on site. Suggestions made during the audit encompass the prescriptive measures that qualify for rebates offered under PG&E's Retrofit Express (Express) program, custom retrofits that could be undertaken and rebated through PG&E's Customized Incentives (CI) program, additional capital improvements for which rebates are not offered, and numerous behavioral changes that could be instituted at the premise. Approximately 5,300 agricultural customers participated in PG&E's 1994 EMS program, and about 15% of these customers went on to participate in PG&E's Express and CI programs in 1994 and 1995.

In our evaluation of the 1994 Express, CI, and EMS program components marketed to the Agricultural sector, we had numerous related questions we were seeking to answer. One of these questions was the extent to which the EMS program drew customers into the Express or CI programs. And if it did draw customers in, was the EMS program drawing the ''right'' kind of customer into the rebate programs? That is, was the EMS program only effective at driving customers with a predisposition to energy efficiency into the Express or CI programs? In quantifying the role of EMS audits in driving efficiency actions, we wanted to statistically control for self-selection effects among those customers who requested or received an audit. It is well known that customers who have heightened awareness of conservation actions may demonstrate a predisposition to seek information (such as a site-survey or, in this case, a site-survey combined with a pump test) and then act on that information. Therefore, in an effort to understand the true scope of the EMS energy audits in driving actions, we wanted to control for this self-selection tendency. Finally, for customers who did not participate in the either of the rebate programs, we wanted to know how many adopted recommended measures outside the Express or CI program because of the auditor's recommendation, again controlling for self-selection.

METHODOLOGY

In order to identify the effectiveness of the audit, independent of self-selection, we implemented multi-stage statistical models. Our first model generated a self-selection correction factor that was used in subsequent analyses to allow other variables to demonstrate unconfounded effects. Similar adoption and participation models were tested to identify predictors of measure adoption and program participation. Specifically, we were looking to see what effect auditors' recommendations had on customers' purchase decisions, and whether these effects differed for general purchase decisions (adoptions) or rebated adoptions. A final, nested model was also tested on a subset of customers. The nested model results were used to compare forecasts of customer measure adoptions with and without auditor intervention. The methods are described in detail below.

Stage One Model: Self-Selection Correction

Certain customers may demonstrate a predisposition to participate in conservation programs or adopt measures outside of programs. Additionally, these customers may also be more attentive to marketing efforts (direct mail campaigns, etc.) than other customers, more likely to be aware of available rebates, and more likely to sign up for energy audits,

when they are available. Since this tendency can also be correlated with natural-conservation tendencies (usually counted as free ridership) self-selectivity corrections (such as the inverse and double inverse Mills techniques) have been proposed for use as corrections in estimating conservation program net impacts. Self-selection corrections suggested by Dubin and McFadden (Dubin & McFadden 1984) have been used in energy and demand impact analyses to control for differences between participant and control groups along dimensions that discriminate the control group from those customers that *self-select* into rebate programs. According to Train (Train, 1986) the selectivity correction term for conditional demand analyses is typically specified as follows:

$$SCT = \frac{P_q * \ln P_q}{1 - P_q} + \ln P_c$$

where

SCT = the selectivity correction term;
P_q = the probability of choosing a non-program-qualifying alternative (given a customer is in the market); and
P_c = the probability of choosing the program-qualifying alternative (given a customer is in the market).

With our data, we developed a model for predicting the likelihood that a customer would request and/or receive an audit, which we believe serves as a proxy for self-selection. This model was based on the customer's rate class and pump application (i.e., does the pump service crops, feed a reservoir, or serve some other function). It should be noted that many of the correlates of self-selection are also ''flags'' that would cause a site to be target marketed. For example, customers might be targeted based on historic usage or rate class. Since access to information (which occurs with target marketing) is correlated with many of the predictors of self-selection/participation, this potentially confounds the *interpretation* of selectivity correction terms (and their use, for instance, in calculating net-to-gross ratios). Still, we felt it was necessary and useful to control for these effects.

Four distinct customer groups contributed data to the self-selection model: ''Ag only'' participants, that is, a subset of the Agricultural program participants (i.e., those who participated in either Express or CI) who did *not* also participate in the EMS program (N = 352); ''Ag + EMS'' participants (customers who participated in both programs—N = 114); ''EMS only'' participants (N = 455); and nonparticipants (who did not participate in any of the three programs, N = 453). Data from all four groups were used to develop the binary choice logistic regression model[1] for predicting the probability that a customer received an EMS audit (the self-selection proxy).

Logit model results were used to obtain probabilities of self-selection for each sample member. These probabilities were calculated in SAS using Proc Logistic. The probability of self-selecting, for any given customer is

$$\hat{p} = \frac{e^{bx}}{1 + e^{bx}}$$

where *b* is a vector of logit regression coefficients and *X* is a vector of values for the different explanatory variables. A probability for self-selection was assigned to each sample member by substituting customer specific values of X into the term, ''bX'', shown above. This term was exponentiated, and the ratio of $e^{bX}/(1 + e^{bX})$ formed the predicted probability of self-selection for each sample point.

Stage Two Models: Predicting Adoptions and Participation

Once probabilities for all customers were generated, they were used in the second stage models to control for self-selection effects. In contrast to the self-selection model, the second stage models only used data from those customers who had received an EMS audit (N = 569). Two sets of models were developed: adoption and participation. The adoption model used adoption of a program qualifying measure as the dependent variable. The binary dependent variable was coded as ''1'' if the customer indicated that any one of a list of program qualifying measures had been adopted (whether or not the Agricultural customer had received a rebate for the measure) and ''0'' otherwise. The participation model was identical to the adoption except the dependent variable in this model was whether or not the customer participated in the Express or CI program. (By definition these customers all adopted program-qualifying measures.)

Independent variables included in all three models were as follows:

- Whether the auditor recommended adopting a capital intensive (usually program qualifying) measure through the program
- Whether the auditor recommended adopting a no-cost/low-cost measure/behavioral change
- Whether the customer actually adopted a no-cost/low-cost measure/behavior
- Satisfaction with the EMS audit
- The self-selection correction factor

Auditor recommendations were believed to be strongly associated with measure implementation, especially adoptions occurring through the rebate programs. The adoption of less costly or purely behavioral measures might reduce the perceived need for additional capital improvements and thereby reduce the likelihood of installing that equipment or undertaking more expensive retrofits. On the other hand, behavioral changes do not compete against other conservation alternatives for cash. This being the case, adoption of no-cost/low-cost measures in tandem with capital intensive changeouts could be a sign of self-selection tendencies. In light of the variable's possible effects (positive or negative), it was provisionally included. EMS audit satisfaction was believed to be positively associated with rebate program participation: if customers were unhappy with the energy audit process or results, they might be less inclined to take advantage of another service offered by the utility (namely the rebate programs). Program qualifying actions that could have been recommended by an auditor are shown in Figure 1. Figure 2 gives a list of no-cost/low-cost actions that could have been recommended and/or adopted.

Nested Logit Model

The nested model further examined the relationship between the customer's choices. (See Figure 3.) The final model tested was a nested combination of the adoption-participation models. In this model, only customers who adopted a program qualifying measure were included in the statistical analysis.

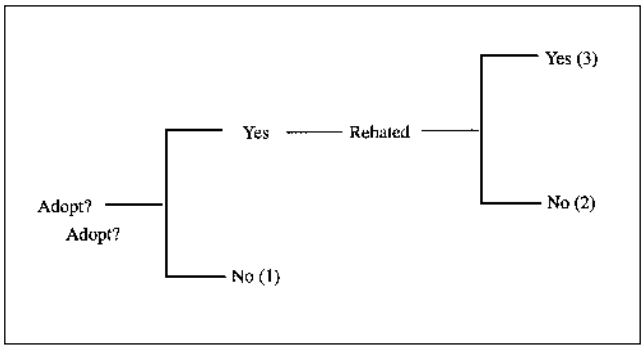
Figure 1. *Capital-Intensive (Program Qualifying) Measures*

- Pump Retrofit
- Pump Adjustment
- Rigid Double-Walled Plastic
- Double-Walled Polyethylene
- Heat Curtain
- Low Pressure Sprinkler Nozzle
- Milk Pre-Cooler
- Refrigerator Desuperheater
- Well Water Measurement Device
- Time Clock with Battery Backup

Figure 2. *No-Cost/Low-Cost Measures*

- Replace fluorescent lights before burnout
- Set time clocks for security lighting
- Turn off lights when not needed
- Use skylights/windows for lighting
- Apply water for storage only in root zone
- Check depth of wetted zone
- Clean dryer air tunnels/adjust air fuel mix
- Keep crop-drying fan belts tight or replace
- Limit high-temperature batch drying
- Water at night or when wind velocity is low
- Water less frequently as crop matures
- Check combustion efficiency on boiler/furnace
- Clean condenser coils yearly on refrigeration equipment/HVAC
- Clean fuel tanks/boiler and change fuel filter
- Ensure adequate ventilation for compressor
- Inspect motor sheaves for end-use equipment
- Repair all leaks in water/steam pipes
- Repair damaged areas of greenhouse
- Maintain electric equipment on a regular schedule
- Service compressor yearly

Figure 3. *Nested Participation Model*



The choice modeled, for those who adopted program qualifying measures, was whether or not to implement through a rebate program. Following Amemiya (Amemiya 1975),

$$P_1 = F(\beta_1' x)$$

$$P2 = [1 - F(\beta_1' x)] * F(\beta_2' x)$$

$$P_3 = [1 - F(\beta_1' x)] * [1 - F(\beta_2' x)]$$

where

P1 = the probability that a customer will not adopt a program qualifying measure
P2 = the probability that a customer will adopt a program qualifying measure, outside the program
P3 = the probability that a customer will adopt a program qualifying measure, through the program

The dependent variable in the nested model was rebate program participation (yes/no), and the set of five independent variables described above were included as regressors. Predicted probabilities for adopting inside and outside the program were compared. A difference score for the two probabilities was computed for each customer, and correlations between the difference score and explanatory variables in the model were examined. Differences in probabilities should be sensitive to variables with purported explanatory power. In other words, if the probability of adopting inside versus outside differs greatly for a given customer, this difference should be correlated with key variables in the nested model.

RESULTS

In general, we saw that the auditor's recommendation seemed to induce measure adoption among customers who had an audit, even controlling for self-selection tendencies. This result held across models and subsets of the data. Results shown in Figures 4–6 show the logistic regression coefficients (B), their standard errors (SE), Wald chi-square values[2], and the probability associated with the parameter estimate for each variable included in the model.

Figure 4. *Adoption Model Results*

Variable	B	SE	Wald Chi-Square	P
Probability of Receiving an Audit	-1.5717	1.1376	1.9089	0.1671
Satisfaction with the Audit	0.0476	0.0921	0.2666	0.6056
Received a Recommendation to Participate	1.1889	0.2428	20.1208	0.0001
Received a Recommendation to Install No Cost/Low Cost	0.1223	0.5512	0.0493	0.8243
Installed/Adopted No Cost/Low Cost	1.7723	0.7755	5.2232	0.0223
Intercept	-0.0083	0.8744	0.0001	0.9924
N	375			
-2LLR	40.29			
P	0.0001			

Figure 5. *Participation Model Results*

Variable	B	SE	Wald Chi-Square	P
Probability of Receiving an Audit	-2.4315	1.4982	2.6341	0.1046
Satisfaction with the Audit	0.0103	0.1247	0.0066	0.9352
Received a Recommendation to Participate	1.4177	0.2857	24.6243	0.0001
Received a Recommendation to Install No Cost/Low Cost	0.9637	0.6161	2.5279	0.1118
Installed/Adopted No Cost/Low Cost	-0.2734	0.7429	0.1355	0.7128
Intercept	-0.8496	1.1544	0.5417	0.4617
N	375			
-2LLR	32.81			
P	0.0001			

Figure 6. *Nested Model Results*

Variable	B	SE	Wald Chi-Square	P
Probability of Receiving an Audit	-1.9469	1.7258	1.2726	0.2593
Satisfaction with the Audit	0.0168	0.147	0.0131	0.9089
Received a Recommendation to Participate	0.9801	0.3276	8.9538	0.0028
Received a Recommendation to Install No Cost/Low Cost	1.3528	0.8862	2.3301	0.1269
Installed/Adopted No Cost/Low Cost	-1.4558	0.9815	2.2000	0.138
Intercept	0.1075	1.3135	0.0067	0.9348
N	172			
-2LLR	13.22			
P	0.05			

Adoption Model

The auditor's recommendation had a striking effect on the customer's likelihood of adopting program qualifying measures ($p < .0001$). With a recommendation to participate, customers were almost three times more likely to adopt program qualifying measures ($e^{1.0889}$)[3]. Merely receiving a recommendation to adopt no-cost/low-cost measures or behaviors did not induce capital intensive improvements (ns). However, customers who *did* adopt these new no-cost/low-cost measures and behaviors were six times more likely to also adopt program qualifying measures ($e^{1.7723}$). Satisfaction with the EMS audit had no effect on capital intensive measure adoptions, either within or outside the Express/CI programs. Those who demonstrated a greater likelihood of receiving an audit were actually less likely to adopt measures

outside the program (as shown by the negative coefficient, although this variable was only marginally significant).

All variables were retained in the model including some that did not attain statistical significance. The overall model -2 log-likelihood ratio, a measure of goodness-of-fit, was 40.29, with five degrees of freedom ($p<.0001$). This indicates a statistically significant model. Data contributed to the final model came from 375 customers, from a possible 569 customers.

Participation Model

As with the adoption model, the auditor's recommendation appeared to exert significant influence on decision-making: auditor recommendations increased the likelihood of participating four-fold ($e^{1.4177}$). Customers who received a no-cost/low-cost recommendation were more likely to participate in the rebate program. However, adopting these new no-cost/low-cost measures and behaviors had no effect on participation ($B = -.2734$, ns). Satisfaction with the EMS energy audit had no effect on participation in the Express or CI programs. Those who demonstrated a greater likelihood of receiving an audit were actually less likely to participate in the Express or CI program ($p<.11$). The overall model -2 log-likelihood ratio was 32.81 ($p<.0001$).

Nested Participation Model

Results obtained were comparable to the first two models: the auditor's recommendation to participate or adopt no-cost/low-cost measures continued to demonstrate a program induction effect ($p<.01$, $p<.15$). The adoption of no-cost/low-cost measures was negatively associated with program participation among those who installed capital intensive measures—a pattern that held from the participation model. Fewer observations were available for the nested model (since this model only included customers who had adopted program qualifying measures). The overall model -2 log-likelihood ratio was 13.22 ($N = 172$, $p<.05$).

Figure 7 shows the correlations between difference scores based on forecasted probabilities of adopting inside and outside the rebate programs. (Pearson and biserial correlations are denoted by R in the table.) The correlation analysis results were consistent with nested model results: the strongest determinant of adoptions within the program was the auditor's recommendation ($r = .89$, $p<.0001$). The directions of the correlations generally followed the nested model results with the exception of no-cost/low-cost adoptions, which followed the pattern in the adoption model: adopting no-cost/low-cost measures is positively associated with adopting within the rebate programs. If this points to self-selection effects, the auditor's recommendation is *still* demonstrating a measurable influence on participation, alongside these possible self-selection factors.

Figure 7. *Difference Score Correlations*

Variable	r	p
Probability of Receiving an Audit	-0.1851	0.0500
Satisfaction with the Audit	0.1445	0.1000
Received a Recommendation to Participate	0.8912	0.0001
Received a Recommendation to Install No Cost/Low Cost	0.4292	0.0001
Installed/Adopted No Cost/Low Cost	0.3186	0.0001

CONCLUSIONS

Our analysis results point to a role for the audits in driving beneficial program participation. Even with a self-selection adjustment factor, the auditors' recommendations still stand out as a driving force in funneling customers into the Express and CI rebate programs. Other evaluation analysis and results confirm the results presented here. Process evaluation results indicated that many customers who were planning to adopt measures *before* they had their audit, subsequently adopted measures *outside* the rebate programs. (Mancuso, et al. 1994)

Approximately 10% of the customers who participated in the 1994 EMS program also participated in one of the 1994 Agricultural programs[4]. Among all customers who participated in the EMS program, 30% received recommendations to participate in the Agricultural retrofit program. Roughly 50% ($\pm 10\%$) of the surveyed customers who participated in both the EMS program and an Agricultural rebate program (Express or CI) reported that they received a recommendation from the auditor to participate. This number stands in contrast to only 25% ($\pm 4\%$) of EMS only customers who reported receiving such a recommendation. Customers who did not receive a recommendation also went to apply for the program, as shown in Figure 8, but EMS customers who received a recommendation from their auditor were three times more likely to participate than EMS customers who did not ($p<.001$). EMS participation alone did not increase the likelihood that a customer would participate in an

Figure 8. *EMS Recommendation Influences*

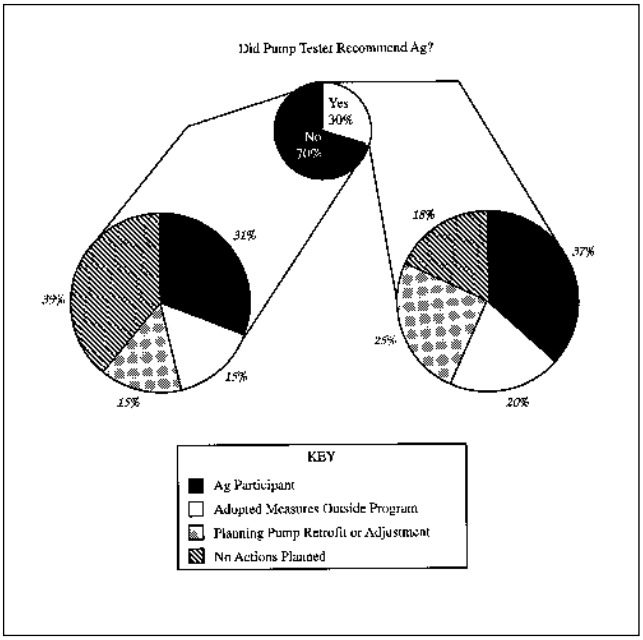
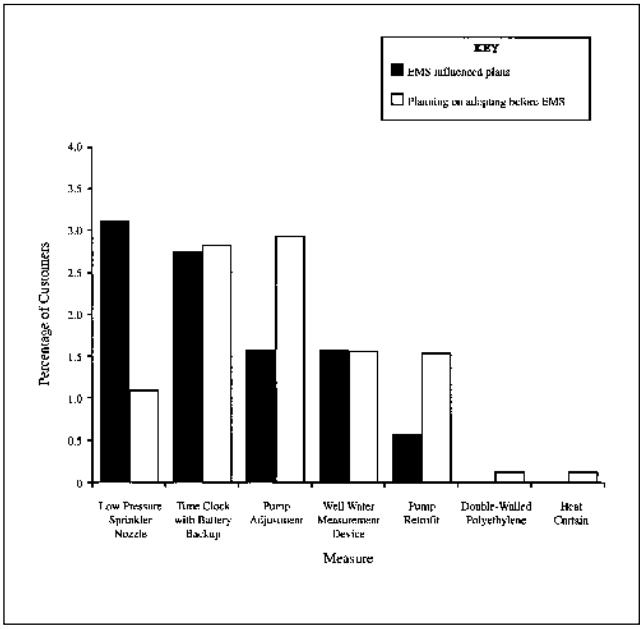


Figure 9. *Rates of Measure Adoption for EMS Participants*



Agricultural rebate program, but receiving a auditor's recommendation tripled the odds of participation, according to the bivariate analysis.

More than 20% ($\pm$3%) of the EMS only participants who received a recommendation to participate in the Agricultural program reported having a pump retrofit or adjustment since their EMS energy audit and pump test. EMS only participants who did not receive a recommendation tended to report fewer pump retrofits and adjustments (15 $\pm$ 3%), although these adoption rates do not differ significantly from those of EMS customers who received recommendations to retrofit. More than two-thirds of the EMS only program participants who had a pump retrofit or adjustment since their pump test reported having plans to adopt these measures *prior* to their pump test.

Approximately 20% ($\pm$3%) of the surveyed customers who participated in the EMS program reported adopting a capital-intensive measure outside the Express or CI programs. As presented in Figure 9, the most frequently adopted measure was a time clock with battery backup: Nearly 6% ($\pm$2%) of the EMS customers surveyed reported installing a time clock with battery backup since their pump test. (Roughly half of these customers stated that they were planning to install this equipment before the pump test.) The most frequently adopted measures directly attributable to EMS participation were low pressure sprinkler nozzles. Approximately 4% ($\pm$2%) of the EMS customers surveyed reported installing low pressure sprinkler nozzles since their pump test. Only 25% ($\pm$3%) of these customers reported previous plans to install the equipment.

In light of customers' self-reports that the EMS audit directly influenced their adoption of measures, and our nested model results, we conclude that the EMS audit program did indeed influence Agricultural customers' purchase plans. The remaining question concerns the quantified benefit of the EMS program. How much energy did the EMS program really save, net of rebate programs? Given the inherent difficulty in measuring impacts in the Agricultural sector (i.e., mapping pumping accounts to premises and premises to decision-makers), we believe that additional work should be undertaken to better specify energy and demand spillover impacts. While the EMS program is drawing the ''right'' kind of customers into PG&E's Agricultural rebate programs, the quantified impact of EMS and rebate program spillover is still open to investigation.

ENDNOTES

1. For regression analyses where the dependent variable takes on limited (i.e., categorical) values, OLS yields biased estimates. One statistical method used with limited dependent variables is the logit model. The logit, or ''logged odds''—ln[p/(1 − p)], is linear in its parameters. That is, an equation can be estimated to fit a set of independent variables to the ratio ln[p/(1 − p)]. Regression coefficients are solved for using maximum likelihood estimation techniques and can be used to generate predicted event probabilities: ebX/(1 + ebX) for the binomial case. In this instance, the event was, ''receive an EMS audit''. See Hosmer D. and S. Lemes-

how. (1989). Applied Logistic Regression. Wiley and Sons: New York.

2. Analogous to a t statistic.

3. The antilog of the regression coefficient is the adjusted odds for that explanatory variable.

4. Based on MDSS data.

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