THE CHANGING ECONOMY AS PART OF DSM IMPACT EVALUATIONS: EVIDENCE FROM A LARGE C&I RETROFIT PROGRAM EVALUATION

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Introduction

The changing New England economy between 1991 and 1993 became an important component in the 1993-1994 evaluation of Boston Edison's Large Commercial/Industrial Retrofit Program. This program had the highest expected energy savings from Boston Edison's demand-side management (DSM) programs. The importance of the program, and the evaluation difficulties previously experienced, due to the unique characteristics of many of the largest savers, created the need for a more comprehensive impact evaluation. It also drove the decision to use new analytical techniques for the billing analysis in this evaluation.

Boston Edison Company's (BECo) Large Commercial/Industrial Retrofit Program provides DSM services to approximately 3,000 customers with a peak demand over 150 kilowatts (kW). The program operates on two fronts; one for institutional customers and one for non-institutional customers. The incentive levels and incentive pay-outs (length of time over which the incentive is paid out to the customer) differ according to the customer types. The institutional customers include buildings owned by governments or hospitals that may face particular financing barriers for making energy efficiency investments. The non-institutional customers include all other large customers, such as manufacturers, and office buildings.

The design for this comprehensive impact evaluation included a two-pronged billing analysis approach combined with a strong engineering analysis. The two-pronged billing approach was also designed to include a high level of disaggregation and attention to detail. Individualized time-series econometric regression was used for some of the largest energy and demand savers. Econometric regression analysis was performed by sector for the other participants using an Analysis of Covariance (ANCOVA) procedure. The procedure allows each participant to act as its own control and reduces the error in the model, allowing a clearer view of the program impact (Megdal, et al., 1995; Ozog, et al. 1995; Hopkins, et al., 1994; Schutte and Violette, 1994; Schiffman, 1994; Megdal, et al., 1993; Summi, et al., 1993; England, et al., 1988; Jasso, 1985; and Hausman, 1981). (See the Megdal, et al., 1995 citation for a more complete discussion of this method and its use in DSM evaluations.)

These methods were complemented by a significant level of examination for potential bias problems, and correction for these problems when they were found. This examination led to the determination that consideration of the economic climate for short-term and long-term savings impacts should be explicitly addressed.

Economic Climate Change and DSM Impacts: Theory and Prior Work

Economic Trends and Consumption

Changes in the economic climate would be expected to change energy consumption. If these changes are not controlled in the regression analysis, this spurious correlation can cause an incorrect savings estimate.

If the economy is in recession, production contraction and/or an income effect will cause a decreasing consumption trend. If this is not accounted for in the econometric analysis, savings will be overestimated. (See Figure 1.) The movement from point A to point B is the observed consumption change. The estimated savings from this difference is represented by the shaded box. Yet, only the blackened box, from point C to point B, is the true program savings. This darker box represents the difference in consumption caused by the program.

Pre-Retrofit

A

Measured Savings

Energy Usage

Post-Retrofit

Reduction due to recession.

Actual Savings

C

B

State of Economy Over Time

Figure 1. Billing Analysis and an On-going Recession

Conversely, billing analysis will underestimate true savings during recovery and growth periods, if the changing economic conditions are not properly controlled in the analysis. (See Figure 2.) In this example, the billing analysis would estimate almost zero savings when true energy savings are much greater, the shaded box being much smaller than the blackened box. The true savings is the difference between the actual post-retrofit consumption at point B and what the consumption would have been without the program, point C.

Measured Savings

Pre-Retrofit

Energy Usage

C

Actual Savings

A

B

Post-Retrofit

State of Economy Over Time

Figure 2. Billing Analysis and an On-going Recovery

Economic Trends and Savings, Interaction Effects

One way in which changing economic conditions are often controlled for in DSM evaluations is through participant/non-participant comparisons. Given the uniqueness of many of this program's customers (the program is targeted to the utility's largest customers) a well-matched non-participant group was unavailable. Even when a well-matched non-participant group is used, this "solution" falls apart if there is an interaction effect between the changing economy and the DSM savings.

A non-participant group can control for any simple effects that impact the participant group. If, however, there is an interactive effect between an unmeasured variable and the variable of interest, this can not be picked up by including a non-participant group in the analysis. The non-participants will not exhibit the interactive effect since they do not have the participation effect.

This leads us to wonder if we can imagine a likely scenario where an interaction between the economic climate and savings would occur. Utilities often pay part of the costs of the investment, with the remainder paid by the customer. This means the decision to participate in the DSM program is made jointly with the investment decision. Businesses more likely to foresee greater future growth are more likely to make significant capital investments. In times of economic recovery, these businesses would be expected to grow faster than the average. Similarly, they would be expected to contract less in recessionary periods. This provides a correlation between expected savings and the economic climate; i.e., the non-participant group is a poor control for this type of economic climate interaction. From this examination, we propose that a changing economic climate would be an issue for all DSM evaluations -- and for commercial and industrial evaluations in particular.

Prior Work

We have found very little prior work where savings estimates were differentiated according to the economic climate. The Northwest Power Planning Council addressed these interactions in a policy and planning document, Northwest Power Planning Council, 1987. The Council determined that long-term savings, rather than changes caused by short-term economic conditions, should be the basis for examining conservation program benefits. A long-term evaluation study at Bonneville Power Administration found savings estimates to vary over time, assumed to be due to changing operating conditions and economic conditions (Doyle and Moe, 1994). A third paper hypothesized the relationship between economic climate and the level of free ridership that might occur, Saxonis, 1991.

Our Findings from the Evaluation of BECo's Large C&I Retrofit Program

Regression and Regression Correction Results

ANCOVA modeling was performed by sector with the largest expected savers removed for individual analysis. The ANCOVA model framework used in the evaluation of BECo's Large C&I Retrofit Program was as follows:

$$E_{it} = \beta_1 S_{itj} + \beta_2 G_{it} + \beta_3 C_{it} + \beta_4 W_{it} + \beta_{5i} + ... + \beta_{ni} + e_{it}$$

where:

E_{it} = Average daily energy consumption for customer "i" in month "t", from the billing data, with the consumption for the billing cycle, divided by the number of days in the billing cycle.

S_{itj} = Dummy variable = 1 if customer "i" in month "t" had installed measure "j"; = 0, if the conservation measure had not yet been installed. For a SAE model, the measure savings' estimates would be included in place of the "1" for the months after installation.

G_{it} = Growth/contraction over time for customer "i" in month "t", as displayed by employment for that customer.

C_{it} = Characteristics within a sector in month "t" for customer "i".

W_{it} = Average weather for customer "i" in month "t", as defined by that customer's billing cycle.

$\beta_1 ... \beta_4$ = Estimated coefficients for entire sample.

$\beta_{5i} ... \beta_{ni}$ = For ANCOVA, customer "i", included as own control for fixed-effects. The coefficients adjust for the customer's base usage, as differentiated from the usage for the sector, based upon the other variables in the model.

e_{it} = Statistical error term, for unexplained variance in observed average daily energy consumption, for customer "i" in month "t".

The coefficient “S” provided either the average daily consumption savings from the measures' installation, or the percentage of the engineering estimate obtained; depending on whether a dummy variable is used, or whether all sample participants have program engineering estimates available for all measures installed. If the engineering estimates were fully available for a sector, these were used, making the model an SAE model type. If not available, this ANCOVA model was a regression adjusted billing analysis.

Modeling was performed for three sectors. These were: manufacturing, office, and schools. In order to simplify this presentation, and keep the paper of reasonable length, all modeling results are not presented. Nevertheless, the results presented in this paper are representative of all our results.

The initial (prior to modeling corrections) manufacturing sector demand model, is a SAE ANCOVA model, for five 1992 manufacturing participants. As shown in Table 1, this model achieves an R-square of 0.96 with a t-statistic for the engineering savings estimate of 8.89. This model provides a realization rate for lighting measures of 105 percent. The weather variable, measured by maximum high temperature, was also very significant. (The maximum high temperature was used as the weather variable since demand usage in a month is related to the month’s peak requirements rather than overall weather, as is given in cooling or heating degree days.) The customer-specific identification variables were very significant for all customers.

(The billing-analysis based realization rate for demand savings was only the first step to derive the demand savings estimates. The final kilowatt savings estimate additionally incorporated a ten-step process in order to get regression-adjusted peak and coincident peak demand savings' estimates.)

Table 1 ANCOVA Results for Manufacturing’s Regression on Demand

R-Square		0.96
Number of Participants		5
Time Period		1/1991 - 10/1993
Number of Observations		300
Variable	Coefficient	t-Statistic
Lighting savings estimate	-1.05	8.89
Maximum High Temperature	1.74	5.60
ANCOVA ID Variables		
ID variables		
ID 26	1,143.78	43.78
ID 36	216.41	8.28
ID 40	399.48	14.99
ID 49	406.46	15.60
ID 50	195.25	7.51

The customer identification coefficients represent the customer's baseline demand consumption for each individual customer. It is the customer's fixed-effect that provides the best fitting sector consumption model. This fixed-effect is similar to have a separate intercept for every customer. ANCOVA's control of fixed-effects for each customer allows the heterogeneity between manufacturing customers to be pulled out of the model, allowing a cleaner estimate of the savings coefficient.

Regression diagnostics were performed on all the models for this evaluation, regardless of how "good" the initial modeling results appeared. Our regression diagnostics included: the probability that the residuals were normally distributed; skewness measurement; kurtosis measurement; a Pearson's correlation coefficient between the residual and the lagged residual; and an examination of residual plots against the predicted values, the savings estimate, average heating degree days, average cooling degree days, and time.

An autocorrelation problem was discovered in the demand model for manufacturing. The residual and lagged residual had a Pearson's correlation coefficient of 0.59. An alternative manufacturing sector model was created that corrects this autocorrelation problem. The corrected model included a trend variable, that would capture the autocorrelation problem, and the downward trend seen in manufacturing consumption over the period. (In fact, the billing analysis had started with data from 1989 through 1993, which had been trimmed to 1991 through 1993 to minimize the effect of the decreasing consumption trend over this period.)

The results from the corrected model for manufacturing demand are shown in Table 2. The trend test model achieves an R-square of 0.96, a t-statistic of 3.66 for the savings estimate, and a t-statistic of 5.15 for the trend variable. The model without the trend variable shows a realization rate of 105%, while the model corrected for autocorrelation shows a realization rate of 55%. This is a very large difference in the realization rate of savings.

Table 2 Alternative Manufacturing Demand Model

R-Square		0.96
Number of Participants		5
Time Period		1/1991 - 10/1993
Number of Observations		300
Variable	Coefficient	t-Statistic
Lighting savings estimate	-0.55	3.66
Trend	-0.05	5.15
ANCOVA Variables		
ID variables		
ID 26	1,834	12.82
ID 36	785	5.75

ID 40	918	6.95
ID 49	1,097	7.75
ID 50	766	5.67
ID interacted with weather and season		
ID 26-0	0.28	0.21
ID 26-1	0.77	0.82
ID 36-0	2.42	2.16
ID 36-1	2.22	2.66
ID 40-0	2.70	2.45
ID 40-1	2.63	3.22
ID 49-0	0.72	0.58
ID 49-1	0.66	0.73
ID 50-0	2.07	1.94
ID 50-1	2.29	2.90

Billing analysis to determine the realization rates for energy savings are much more common than demand models. Energy models were also developed in this evaluation. The energy model specifications included interactions between weather and the customer identification variable. This allowed each customer to have its own response to weather.

The results for the non-trend model, for energy usage by the manufacturing sector, are presented in Table 3. This model found a realization rate for the lighting energy savings of 111%. A similar test of the trend variable was performed for manufacturing's energy model. These results are shown in Table 4. Here again, the realization rate dropped dramatically. The energy savings realization for the trend model is 65%.

Table 3 Energy Model for the Manufacturing Sector

R-Square	0.98
Number of Participants	5
Time Period	1/1991 - 10/1993
Number of Observations	180

Variable	Coefficient	t-Statistic
Lighting savings estimate	-1.11	8.28
ANCOVA Variables		
ID variables		
ID 26	14,955	57.62
ID 36	3,498	13.36
ID 40	4,455	16.28
ID 49	4,090	16.54
ID 50	2,440	9.78
ID interacted with average HDD		

ID 26	32	2.92
ID 36	23	2.04
ID 40	6	0.60
ID 49	13	1.23
ID 50	0	0.02
ID interacted with average CDD		
ID 26	74	1.75
ID 36	126	2.87
ID 40	127	3.15
ID 49	38	0.90
ID 50	143	3.41

Table 4 Alternative Energy Model for the Manufacturing Sector

R-Square	0.99
Number of Participants	5
Time Period	1/1991 - 10/1993
Number of Observations	180

Variable	Coefficient	t-Statistic
Lighting savings estimate	-0.65	3.58
Trend	-0.70	3.70
ANCOVA Variables		
ID variables		
ID 26	23,157	10.37
ID 36	11,823	5.22
ID 40	12,442	5.72
ID 49	12,426	5.48
ID 50	10,830	4.75
ID interacted with average HDD		
ID 26	29	2.78
ID 36	19	1.76
ID 40	9	0.88
ID 49	9	0.92
ID 50	-5	0.44
ID interacted with average CDD		
ID 26	74	1.79
ID 36	120	2.84
ID 40	136	3.49
ID 49	31	0.76
ID 50	136	3.36

The models corrected for autocorrelation could have been selected as “the” final evaluation results. That is, the manufacturing demand realization rate for this evaluation could have been assumed to be 55%, and the energy realization rate to be 65%. We did not make this more simplistic assumption.

The trend variable probably indicated the strength and length of the 1991-1993 recession in New England, particularly in its manufacturing sector. The employment data collected for these participants was not a significant variable in the analysis. However, intensities of usage of space and production capacity are much easier for a firm to adjust than employment; given hiring and firing costs, union contracts, and unemployment costs. An employment level variable also can not pick up the recession's impact on production and energy usage unless its changes correspond very closely in time with energy consumption changes. This means that the employment indicator variable may not be capturing the full impact of the firm's response to the economy that may, in turn, cause a reduction in consumption. We know that a declining economy improperly modeled can over-estimate the actual program savings. We first attempted to minimize this problem by limiting our billing analysis to the 1991 through 1993 period. The longer time-series available was from 1989 through 1993, all of which was within the manufacturing recessionary period in New England. When this did not work we incorporated the trend variable.

The trend variable, for the time period of our analysis, is capturing the recessionary impact. We know this recessionary impact is interactive with our savings estimate, because the realization rate changes dramatically when the trend variable is included. Nevertheless, we do not believe that this recessionary impact will last forever. This is complimented by a comparison of engineering findings for the largest manufacturers (not included in the manufacturing sector analysis) and the non-trend sector model. A detailed engineering analysis was performed for the largest manufacturers. This analysis included engineering audits, spot metering, and review of the program's metering results for ten percent of the installations. The energy analysis found energy savings' realization rates of approximately 105%. This is only slightly lower than the non-trend billing analysis, that had a realization rate of 111%. The engineering analysis also pointed out that the original savings estimates did not include interactions between measures, a significant impact to overall program savings for many customers.

Given all of the above, the final manufacturing sector realization rates are differentiated by those assumed to be occurring during the recessionary and those expected after economic recovery. The 65% realization rate for energy and 55% for demand, from the trend model, were selected as the realization rates for this sector for 1992 and 1993. After economic recovery, the plants would be expected to come back up to full capacity. Therefore, the 111% realization rate for energy and the 105% realization rate for demand, from the non-trend model was selected for 1995 and beyond. (The New England recovery began in earnest in 1994.) A mid-point realization rate was selected for 1994.

We believe this to be the first time that DSM realization rates have been estimated to vary over time, depending upon interaction with the economic climate. It is not customary for DSM evaluations to contain complete regression diagnostics. It is quite possible that these factors have been operating in other evaluations, and have gone unnoticed. We recommend further study into the interactive nature of savings and economic climate. This is needed for more accurate short-term and life-time savings' estimates. It also could prove important to understanding the correct over-time annual average of savings to be expected from DSM programs. We may now have estimates that are too low based upon analysis occurring during economic recovery, or too high based upon analysis occurring over a recessionary period.

Conclusions

The changing New England economy between 1991 and 1993 became an important component in the 1993-1994 evaluation of Boston Edison's Large Commercial/Industrial Retrofit Program. The regression diagnostics from the billing analysis, and supporting evidence from on-site audits, provided the basis for explicit treatment of the changing economy in the savings estimates. The evaluation's savings estimates for the manufacturing sector, and an individual large customer, were differentiated between those expected to have actually occurred (in 1992 and 1993), and those to be expected during, and after economic recovery (1994, 1995 and beyond). That is, the savings estimates vary over time, as they are expected to change with the changing economic conditions.

We think this is the first time that a demand-side management (DSM) evaluation has looked for economic interactions, and made separate DSM estimates according to the state of the economy. The evidence found in this study, and the intuitive reasons to expect these types of interactions, lead us to believe that many prior evaluations may have unknowingly been biased by excluding this type of examination. We also believe that it would useful to have this issue studied in the future, across different types of economies, DSM programs, and over time across several business cycles.

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