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AN ECONOMETRIC INVESTIGATION OF THE IMPLICIT DYNAMICS IN INTEGRATED LEAST COST PLANNING: AN ASYMMETRIC DYNAMIC ADJUSTMENT MODEL

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Introduction

Now-a-days many electric utility companies throughout the U.S. are involved in Integrated Least Cost Planning (ILCP). In ILCP, demand side and supply side options are integrated into plans to achieve corporate objectives and regulatory targets for providing better and fair electric services at the least cost over a specified time horizon. The resource plans should contain an optimal set of demand side and supply side options. We know that in the electric utility sector, sufficient energy losses occur in an electric system during transmission, distribution and other intermediate processes and during final consumption. So, in order to implement Integrated Least Cost Planning, it is worth investigating the linkage between the supply side and demand side through the dynamics of electric generation, sales, and energy losses in the system.

Electric companies, under regulatory constraints, make efforts to meet load targets. During this process, the possibility of "under shooting" or "over shooting" the desired levels arises as a common phenomenon in the regulated industry. Until now, empirical studies have not investigated the dynamic behavior of these elements in Integrated Least Cost Plans nor have they tested the linkage between the demand and supply side activities through their important determinants. This study develops an econometric model which captures some of the linkages between the demand and supply side. This is based on an asymmetric dynamic partial cost adjustment process. The behavioral implication of this process is that the costs of deviating from the target level and the costs of moving from the existing level are treated asymmetrically so that their rates of adjustment are different. Different weights are given

level will be somewhere between the previous level and the desired level. A partial adjustment model which reflects the tradeoff between those costs is developed by minimizing the costs of moving between the existing and target levels. Thus, the model estimates the relative speed of adjustment for both demand and supply side options, and explains the implications of important policy variables with regard to integrated least cost plans.
The empirical findings of this study will provide an extended outlook to regulators and utility companies about the implicit dynamics in the integration of the demand side and supply side for Least Cost Planning.

Econometric Framework

Structural changes in demand and supply side options of a utility arise due to asymmetry in the adjustment mechanism (e.g., overshooting and undershooting the target values) in a utility's planning process. Applications of such an asymmetric adjustment process can result in some worthwhile achievements. The focus in this paper is centered on the application of different weights for undershooting and overshooting a utility's targets in the context of some economic planning models.

In studying such an adjustment process of a utility, we have considered an Asymmetric Partial Adjustment Model. The theoritical formulation of the model in contained in the Appendix. The formulation is based on the contention that a utility minimizes its costs. For illustration, consider the value of a utility's demand reduction variable at a certain period and its corresponding target level. Then assume a cost function (equation (1)) which measures the dynamics of attaining the current value of demand reductions in a particular period in relation to its targeted level, given the demand reduction level achieved by the utility in the preceeding period. The cost function is considered to have two components. The first one measures disequlibrium costs, i.e., the costs of deviating from the target level. The second cost component measures transactions costs, i.e., the costs of changing the current level of demand reduction from its previous level. Minimizing the cost function with respect to demand reduction will imply the partial adjustment behavior of the utility in this process as shown in the Appendix (equation (2)).

Now, let us consider the cases of undershooting and overshooting the target levels as a utility moves from the previous level. Here, we insert the element that a utility

might undershoot or overshoot its desired level of demand reduction, and its current level of demand reduction might be higher or lower than its previous level (equations (4) and (5) in the Appendix). Thus they represent the asymmetric behavior of the utility. Now, minimizing both the cost components with respect to demand reduction, we obtain Asymmetric Partial Adjustment Model (equations (6) and (7) in the Appendix). It is worth noting that such adjustment models are certainly useful to estimate the performance of a firm with respect to its demand and supply side activities. We should also state that such models can also incorporate adjustment mechanism of other variables with respect to a target level or the previous level as discussed above.

In the next section, in order to conduct a preliminary investigation on the performance of a utility with the interactions of its demand and supply side and their important determinants and policy implications, we have established an empirical set-up based on this framework.

Empirical Analysis

For the empirical analysis we have considered demand side reduction as one of the key determinants to a utility which is involved in the dynamics of its integrated least cost planning. The whole process of the dynamics to be investigated empirically has been presented below in a schemetic diagram:

DYNAMICS OF DEMAND REDUCTION WITH DEMAND AND SUPPLY-SIDE INTERACTIONS

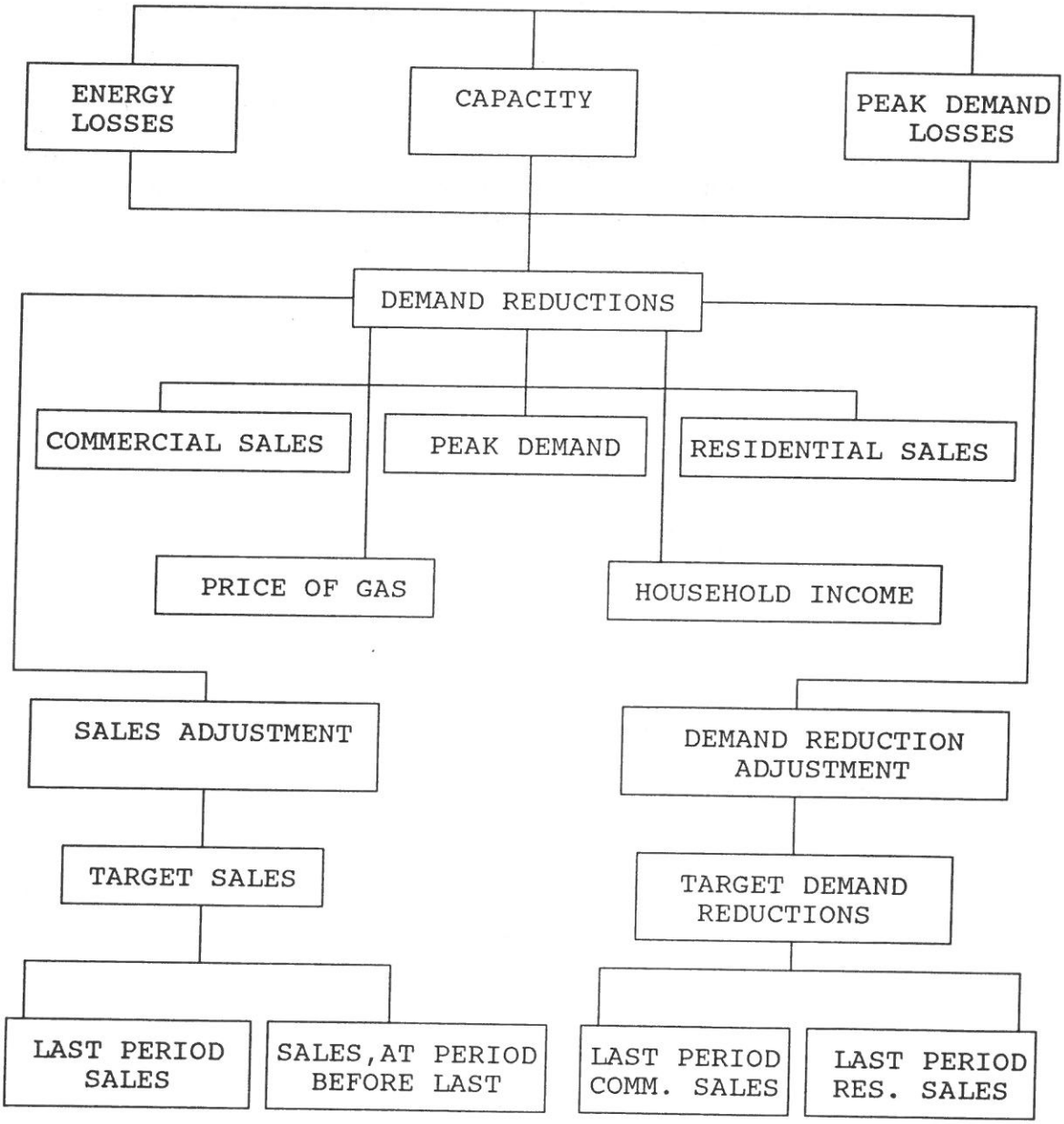

Fig. 1

Initially, we test whether there is any interaction of the change in demand reduction or saving with supply side capacity, transmission and distribution such as changes in energy losses, peak demand losses and changes in the capacity. Accordingly, we also fit a demand reduction function based on key demand side variables.

Next, we assume that in order to achieve a target demand reduction level, while a utility makes efforts to adjust its demand reduction it also makes its sales adjustment against a desired level. So in this empirical work we used the framework of partial adjustment model discussed in the previous section, where we assume that a estimated or desired level of demand reduction/saving depends on commercial and residential sales of the last period and desired sales level is function of previous sales.

The key objectives of this empirical application are the following:

A. Assess the dynamics of a utility's demand reduction in its least cost plan and the importance of other explanatory variables in this regard.
B. Determine the policy implications and relative importance of the cost of deviating from a target level and of moving from its previous level of its sales and demand reduction.
C. Evaluate a utility's performance by determining the speed of adjustment of its sales and demand reductions.

Data and Variables Description

We have compiled data from the Potomac Electric and Power Company (PEPCO) in Washington D.C. PEPCO provided these data as part of its 1990 Energy Plan. However, at this stage of the implementation of integrated least cost plannings, it is not feasible to obtain adequate data for this type of analysis. Thus we had to overcome this problem by developing relevant data sets through the use of forecasting and backcasting techniques, and also using PEPCO's projected data on different variables. For example, historical time series data for demand reductions/savings are not available. Instead, we used PEPCO's projected demand-side reduction data.
Because of the data limitation, we also had to restrict our analysis to some extent. We could not execute Maximum Likelihood Estimation procedure because of the nature of the conditional likelihood function and lack of data points for which convergence could not be achieved. We tried different

methods for estimation, but we could not obtain global maxima, biased estimates of the parameters were generated. Thus, we could not empirically estimate 'overshooting' and 'undershooting' parameters of the adjustment model.

The following is an exhibit with a brief description of the variables used in the analysis:

Variables	Description
DR_t	Demand reductions/savings at period t
EL_t	Energy loss at period t
PDL_t	Peak demand loss at period t
C_t	Capacity at period t
PD_t	Peak demand at period t
CS_t	Commercial sales at period t
RS_t	Residential sales at period t
PGS_t	Price of gas at period t
RIH_t	Real income per household at period t
S_t	total sales at period t
S_t^*	Desired or estimated sales at period t
DR_t^*	Desired or target demand reduction /saving at period t
Δ	Time difference operator, changes from period t-1 to period t
t	time period
t-1	previous time period

Results and Analysis

In this section we present the following estimated equations:

1. Changes in Demand Reduction with Supply Side Interactions
2. Demand Reduction Function
3. Sales Adjustment
4. Demand Reduction Adjustment

Changes in Demand Reduction with Supply Side Interactions:

$$\Delta DR_t = \mathbf{A_0} + \mathbf{A_1} * \Delta EL_t + \mathbf{A_2} * \Delta PDL_t + \mathbf{A_3} * \Delta C_t + \text{Error} \quad \text{-------(8)}$$

$$R^2 = 0.8681$$

$$\Delta DR_t = \underset{(13.740)}{155.6172} + \underset{(-1.064)}{-17.1774} * \Delta EL_t + \underset{(1.969)}{0.1889} * \Delta PDL_t + \underset{(-0.981)}{-0.0273} * \Delta C_t$$

$$\text{----------(8a)}$$

Demand Reduction Function:

$$DR_t = \mathbf{B_0} + \mathbf{B_1} * PD_t + \mathbf{B_2} * CS_t + \mathbf{B_3} * PGS_t + \mathbf{B_4} * RIH_t + \text{Error}$$

$$\text{----------(9)}$$

$$R^2 = 0.9950$$

$$DR_t = \underset{(-3.792)}{864.108} + \underset{(1.384)}{0.0517} * PD_t + \underset{(7.472)}{0.3069} * CS_t + \underset{(2.386)}{197.3998} * PGS_t$$

$$+ \underset{(-3.894)}{-.00287} * RIH_t \quad \text{----------(9a)}$$

Sales Adjustment:

$$\Delta S_t = \alpha_1/(\alpha_1 + \beta_1) * (S_t^* - S_{t-1}) \quad \text{----------(10)}$$

where, $S_t^* = \underset{(4.772)}{0.9872} * S_{t-1} + \underset{(0.061)}{0.0126} * S_{t-2}$ ----------(10a)

and $\alpha_1 = \underset{(2.0257)}{0.0796}$, $\beta_1 = \underset{(1.984)}{0.7076}$, $\delta_1 = \alpha_1/(\alpha_1 + \beta_1) = .11$

Demand Reduction Adjustment:

$$\Delta DR_t = \alpha_2/(\alpha_2 + \beta_2) * (DR_t^* - DR_{t-1}) \quad \text{----------(11)}$$

where, $$DR_t^* = \underset{(13.206)}{0.3232} * CS_{t-1} + \underset{(-0.797)}{-0.00805} * RS_{t-1} \quad \text{----------(11a)}$$

and $$\alpha_2 = \underset{(2.487)}{0.8828}, \quad \beta_2 = \underset{(1.961)}{11.1225}, \quad \delta_2 = \alpha_2/(\alpha_2 + \beta_2) = .08$$

Discussion of the Results

A. In equation (8a) the estimated parameter for the variable ΔPDL_t is only statistically significant at 2.5% probability level. It shows that the changes in the peak demand loss of the utility is positively related to changes in the demand reductions. Other changes such as energy losses during transmission and distribution and changes in capacity have statistically insignificant effect on the change in the demand reduction or saving.

In this regard, it is important to note that the equation (9) provides some interesting results for assessing the ipmact of some of the important demand side determinants on the utility's demand reduction. It shows that the contribution of peak demand variations to a utility's demand reduction is not statistically significant, whereas its commercial sales have a significant effect. As demand in the commercial sector carries a significant share of a utility's peak demand, the result implies that commercial users might not be interested to save energy during peak. We also tested an alternative specification which statistically reveals an established fact that the utility's residential sales contributes less in demand reduction compared to that by commercial sales. The statistical significance of the coefficient of the variable RIH_t in the specication (9) also reconfirms the fact that households with higher income have less propensity to save electricity. The sign of the estimated coefficient is negative.

This analysis also explores an important element of inter-fuel substitutability. It shows that price of gas has significant effect on the demand reduction by an electric utility.

B. Comparing the estimated αs with βs from the sales and demand reduction adjustment models, equations (10) and (11), we find that, for PEPCO, in the both sales and demand reduction adjustment processes, the estimated transaction cost parameter β is higher than α, the parameter for the cost of deviating from its desired levels of sales or demand reduction is higher. This result reflects the fact that PEPCO does not suffer more without attaining its desired level of sales or demand reduction, than without exceeding its previous levels of the sales and demand saving of the preceeding period. It implies that short-run target levels for PEPCO's demand reduction and sales are of less importance at this stage of its planning process. This analysis of the sales and demand reduction adjustments also shows that that the short-run desired level of sales and demand reduction depends sinificantly on the last period's sale and last period commercial sales respectively (Equations (10a) and (11a)).

C. The calculated value of δ_1 is the speed of adjustment of the utility's sales. From the adjustment mechanism (equation 2) the δ should lie between 0 and 1. Higher the value of δ within this range better the performance towards attaining the desired levels. In our case, δ_1 is the speed of adjustment of the sales towards attaining the desired level of sales, δ_2 is the speed of adjustment of the demand reduction toward attaining its desired level. The values of δ_1 and δ_2 are .11 and .08 respectively. Even though the speed of adjustment of sales is higher than that of the demand reduction, but both are far below unity. It shows poor performance in achieving target levels. We should keep in mind because of data limitation we could not incorporate the asymmetric adjustment mechanism to this analysis which could provide better understanding of the adjustment performance of a utility.

Conclusions

The above discussion covered the three key objectives of this econometric investigation. We would like to add the following concluding remarks based on the interesting findings of this empirical analysis:

1. In the integrated least cost planning peak demand losses are also one of the important factors in the linkage of demand and supply side determinants which should not be ignored.

2. Utilities should enhance their commercial programs and should make consistent efforts to capture lower income groups in the residential sector. In the prospective of demand saving they should give special emphasis on developing and designing such residential programs which capture lower income customers.

3. On their way of least cost planning process, utilities should not ignore inter-fuel substitutability or dependence. This important element should be considered while a utility develop its demand and supply side programs for its least cost planning.

4. Both sales and demand reduction adjustment process of each utility should be empirically evaluated periodically which will reflect their respective speed of adjustment and progress in achieving the target levels in the planning process and in attaining success in their least cost planning ventures.

Finally, we should mention that this is a preliminary exposition of such analytical investgation. There are enough rooms for future work within the similar framework in improving the model and variable specifications with respect to various objectives.

Appendix

The following theoritical formulations are based on Dr. D. J. Poirier's works (Poirier (1973, 1975, 1976), Poirier and Garber (1974).[1]

Theoretical Formulations:

Let y_{t*} be the value of a utility's y variable at period t, and let y_t^* be its corresponding target level. Then for $\alpha > 0$ and $\beta > 0$, the cost function

$$C = \alpha(y_t - y_t^*)^2 + \beta(y_t - y_{t-1})^2 \quad \ldots\ldots\ldots\ldots\ldots (1)$$

measures the dynamics of y attaining the value y_t in period t, given that its target level is y_t and that its value acieved by a utility in the preceeding period was y_{t-1}. The first term of (1) measures disequlibrium costs, i.e., the costs of deviating from the target level. The second term of (1) measures the costs of changing the actual level from the previous level as from y_{t-1} to y_t.

Now, minimizing (1) with respect to y_t will imply the partial adjustment behavior of the utility in this process, as

Partial Adjustment Model:

$$y_t = y_{t-1} + \alpha/(\alpha + \beta)\ (y_t^* - y_{t-1}) \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Now, let us consider cases of undershooting and overshooting the target levels and moving from the previous level as discussed above with reference to the two types of cost components. For such cases we redefine the above loss function as

$$C = C_1(y_t;y_t^*) + C_2(y_t;y_{t-1}) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

where, the cost component of undershooting and overshooting the target level is given by

$$C_1(y_t;y_t^*) = \left\{ \begin{array}{ll} \alpha_1(y_t - y_t^*)^2, & \text{if } y_t \le y_t^* \\ \alpha_2(y_t - y_t^*)^2, & \text{if } y_t \ge y_t^* \end{array} \right\} \ldots\ldots (4)$$

and the cost component for deviating from the previous level is given by

$$C_2(y_t;y_{t-1}) = \left\{ \begin{array}{ll} \beta_1(y_t - y_{t-1})^2, & \text{if } y_t \le y_{t-1} \\ \beta_2(y_t - y_{t-1})^2, & \text{if } y_t \ge y_{t-1} \end{array} \right\} \quad \ldots\ldots(5)$$

and α_1, α_2, β_1 and β_2 in (4) and (5) are positive parameters.

Now, minimizing (3) with respect to y_t will imply the asymmetrical partial adjustment behavior of the utility, as

<u>Asymmetric Partial Adjustment Model</u>:

$$y_t = y_{t-1} + \alpha_i/(\alpha_i + \beta_j)\ (y_t^* - y_{t-1}) \quad \ldots\ldots\ldots\ldots\ldots(6)$$

where, $i = \left\{ \begin{array}{ll} 1, & \text{if } y_t \le y_t^* \\ 2, & \text{if } y_t \ge y_t^* \end{array} \right\}$, and

$$j = \left\{ \begin{array}{ll} 1, & \text{if } y_t \le y_{t-1} \\ 2, & \text{if } y_t \ge y_{t-1} \end{array} \right\} \quad \ldots\ldots\ldots\ldots\ldots(7)$$

where, the adjustment parameters or speed of adjustment coefficients are $\delta_i = \alpha_i/(\alpha_i + \beta_j)$.

<u>Note</u>: In this paper, we have considered sales and demand reduction adjustments (Fig. 1). So y variable in the above formulation represents the utility's sales or demand reductions.

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