Energy Efficiency and Retail Electricity Shopping: Competing Goals or Complementary Goals?

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ABSTRACT

Residential customers can shop for electricity for the generation portion of their bill in a number of states. Select examples of these states are Pennsylvania, Connecticut, New Jersey, Maryland and Rhode Island. Also, it is not uncommon for local utilities in these states to offer incentives/ rebates to customers for making energy efficiency improvements – for example, PECO in Philadelphia, PPL Electric in eastern and central Pennsylvania and PSE&G in eastern New Jersey. Customers who typically shop for electricity are looking to find a lower marginal price on cents/ kWh basis and lower their monthly electric bills. All else being the same, a lower electricity price should increase the demand for electricity – in standard economics parlance; this is a downward movement along a demand curve. On the other hand, all else being the same, installing an energy efficient measure compared to the standard option (e.g. CFLs compared to incandescent bulbs) should lower electricity consumption. Using PPL Electric's residential segmentation, energy efficiency and customer billing databases, this study attempts to quantify the impacts of retail electricity shopping and participation in energy efficiency programs on electric consumption. The finding of this study may have significant policy ramifications. Typically, regulators want to promote both electricity shopping and energy efficiency. But, it is still an empirical question whether these two are competing goals or mutually compatible goals. To the degree these are largely competing goals, a regulator may have to choose one over the other, which by no means is an easy choice.

Introduction

In recent times, Pennsylvania has enjoyed significant growth in the area of energy efficiency. The main reason for this growth is Act 129. This legislation, signed October 15, 2008, mandates energy savings and demand reduction goals for the largest electric distribution companies (EDCs) in Pennsylvania. Specifically, each EDC is required to reduce electric load by 3% of its 2009-2010 sales forecast by May 31, 2013. Pursuant to those goals, energy efficiency and conservation (EE&C) plans were submitted by each EDC and approved by the Pennsylvania Public Utility Commission (PUC).

PPL Electric Utilities Corporation ("PPL Electric" or the "Company"), a subsidiary of PPL Corporation, headquartered in Allentown, PA, distributes electricity to approximately 1.4 million residential, commercial and industrial customers in eastern and central Pennsylvania. Act 129 mandates the Company to achieve 1,146,000 MWH/yr of electric savings by May 31, 2013. To comply with this requirement, the Company created a suite of energy efficiency programs for its customer base, and launched most programs in the second half of 2009. Key programs launched for residential customers were Residential Lighting Program, Appliance Recycling Program, Efficient Equipment Incentive/Rebate Program, Behavior & Education Program, Winter Relief Assistance Program (WRAP) and Home Energy Assessment & Weatherization Program.

Since early 2010, retail electric shopping like energy efficiency, has enjoyed considerable success in Pennsylvania, particularly in the Company's service territory. Two factors have contributed to this success – the Company's efforts starting in late 2009 to educate customers about the lifting of rate caps resulting in a

30% increase in the generation component of default rates, and entry of a large number of competitive generation suppliers in the market place. For the last three years, more than 20 suppliers have competed in the Company's service territory to attract residential customers. These suppliers offer a wide array of choices to customers such as fixed rates that can be locked in for a period of 6 to 12 months into the future, monthly variable rates, additional discounts for not switching to another supplier in a specified time window, and an option to buy electricity made by renewable resources such as wind, solar, etc.

Scope and Methodology

The focus of this paper is to address the following research questions:

1. What are the trends in residential electricity shopping and energy efficiency participation? How do these trends fare by income and house size?
2. What has been the impact on the Company's residential per household electricity consumption due to Act 129 and development of a robust retail electricity market?

We utilized relevant data from the Company's billing, energy efficiency tracking and segmentation databases to answer the first question above. Specifically, monthly billing data from the Company's Customer DataMart (platform to access customer billing data) is used to determine trends in electricity shopping; data from the Company's Act 129 Energy Efficiency Management Information System (EEMIS) is used to determine participation trends in energy efficiency programs. Last but not least, the Residential Segmentation Database maintained by the Company's Market Research Division is used to establish energy efficiency and retail shopping trends by income and house size.

The basic approach followed to address the second research question above is to create a regression model of monthly average electric use per customer (UPC). Conceptually, UPC can be expressed as follows: UPC = *f*(weather, income per capita, electric price, efficiency index to reflect naturally occurring conservation, program driven energy efficiency indicators such as ARRA, seasonal trends, random error component)

In the framework above, weather is usually expressed in terms of Heating Degree Days (HDDs) and Cooling Degree Days (CDDs). Income per capita is considered to be a proxy for appliance stock. The idea is that an increase in income levels results in more plug loads (such as TVs, lamps, etc.) and more weather sensitive devices (such as space heaters, dehumidifiers, etc.) purchased, and vice versa. Electric price used is an average price, i.e., total bill divided by total usage, and not marginal price.[1] Both income per capita and average electric price are adjusted for inflation. Monthly dummies are used to capture seasonal trends such as start of daylight savings time in March, installation of Christmas lights during the holiday season, etc. Information gathered from market research surveys such as appliance penetration/ saturation and vintage is used to construct the efficiency index. However, if these surveys are not conducted often (let's say once every 1-2 years), then it is common to use a time-trend as a proxy for the efficiency index.

Utilizing historical data for the January 2000 – May 2009 time-period, a regression model of UPC is created. Since it is common to have serial correlation in time-series data, a correction is made to account for it. The coefficient estimates resulting from this model are then multiplied by the actual values of corresponding independent variables for June 2009 – Dec 2012 time-period to create an "unconstrained" forecast by month. This forecast is unconstrained in the sense that it has no influence of either Act 129 or retail shopping baked in it because the last observation used in the model estimation is May 2009, which

[1] While economic theory would suggest using marginal price, most customers are generally not aware of the marginal prices they pay at the time of consuming electricity. Also, customers generally respond to the overall size of the bill and not monthly fluctuations in marginal price.

precedes both the launch of Act 129 in June 2009 and retail shopping in January 2010. Conceptually, if one is to compare this forecast against the actual UPC by month, the difference is the sum of Act 129 net energy savings[2] and retail shopping impacts, plus a random error term. Mathematically, this relationship can be expressed as follows:

Equation 1: $UPC_{UNCONSTRAINED} - UPC_{ACTUAL}$ = Act 129 Net Impacts + Shopping Impacts ± Error

It turns out that it is relatively easy to estimate the per customer impact of shopping on consumption. Beginning January 2010, a monthly price time-series was constructed for shopping customers by summing the monthly billed revenues attributable to all competitive suppliers, and dividing these revenues by total billed sales and consumer price index. Multiplying the slope of electric price variable from the regression model by the difference in default price and shopping price provides an estimate of shopping impact on a monthly basis for the January 2010 – January 2013 time-period.

Estimating the impact of Act 129 on electricity consumption turns out to be a bit more complicated considering that the sign and magnitude of the error term is generally not known. In order to understand this point better, it is useful to know that Equation 1 above can be rearranged as follows:

Equation 2: Act 129 Net Impacts = $UPC_{UNCONSTRAINED} - UPC_{ACTUAL}$ – Shopping Impacts ± Error

If the error term in Equation 2 is assumed to be zero, it becomes fairly easy to estimate Act 129 net impacts because values for all terms on the right hand side of the equal sign are already known. However, not knowing the extent of this error, it makes more sense to utilize net savings reported by PPL Electric's Act 129 independent evaluator, The Cadmus Group, Inc. ("Cadmus") to the PA PUC. For each of the Company's Act 129 energy efficiency programs, Cadmus estimates verified gross savings, free-ridership and spillover impacts to determine net savings impacts. Typically, Cadmus performs this analysis for each Act 129 program year (which runs from June through May) and reports the findings in PPL Electric's Annual Report due to the PUC in mid-November. While it is useful to have net savings impacts by program, caution is still needed to interpret these figures for the purposes of this study. Verified gross savings, which are one of the key inputs for net savings, are based in large part on the measure savings protocols established in PA's Technical Reference Manual (TRM). All of the protocols (deemed and partially deemed) in PA TRM provide estimates of annualized savings regardless of the timing of installation of a measure within a given program year. So, in other words, an energy efficiency measure installed on the first day of a program year receives the same savings as that of an identical measure installed on the last day of the program year. Also, for a majority of residential measures in PA TRM, replacement on burnout assumption is used to determine savings estimates. From a customer's usage (meter) perspective, timing of installation of an energy efficiency measure and assumptions about the baseline condition (early replacement versus replacement on burnout), both matter.

Results

Discussion of Trends in Residential Electricity Shopping and Act 129 Energy Efficiency Participation

As of April 2012, approximately 42% of PPL Electric's 1.2 million residential customers were shopping for electricity. Similarly, 22% of the Company's residential customers were participating in one or

[2] Since Act 129 Gross Savings Impact also include energy savings from naturally occurring conservation, it is appropriate to use Net Savings for the purposes of this Study.

more downstream Act 129 energy efficiency programs.[3] Table 1 on next page shows a cross-tabulation of downstream Act 129 participation by Shopping. Approximately 12% of the Company's residential customers were participating in both Act 129 and Retail Shopping. On the other hand, there is a sizeable percentage of customers (48%) who were neither shopping nor participating in Act 129 programs.

Table 1. Act 129 Downstream Program Participation by Shopping (%)

Choice of Enrollment	Participation in Act 129		
	No	Yes	Total
Not Shopping	47.7%	10.5%	**58.2%**
Shopping	30.2%	11.6%	**41.8%**
Total	**77.9%**	**22.1%**	**100.0%**

As shown in Figure 1, Shopping customers participate at a higher rate in Act 129 compared to those customers who don't shop. Similarly, Act 129 participants shop at a higher rate compared to Act 129 non-participants (Figure 2).

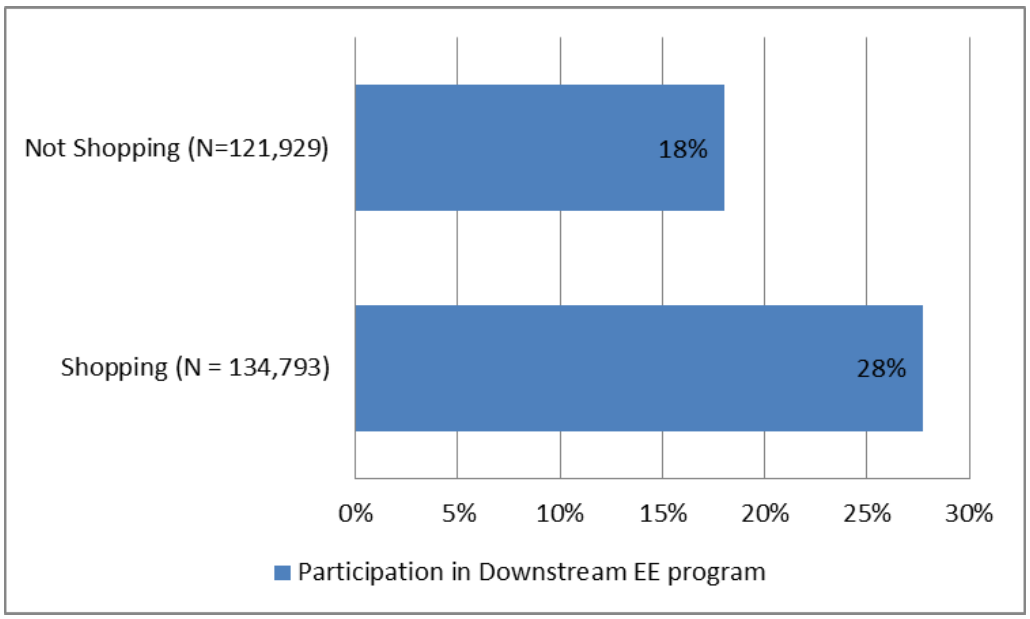

Figure 1. Percentage of Participants in Act 129 by Shopping

[3] The Company also has an upstream Residential Lighting Program. Because of the upstream nature of this program, the actual customers who participate in it are not known for the entire population, and hence not counted in this analysis.

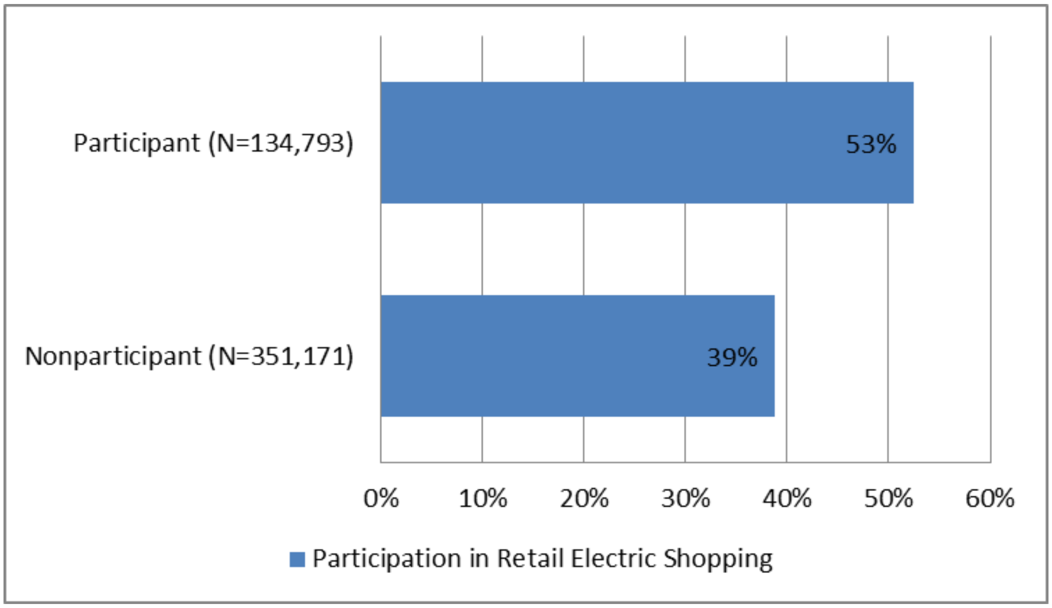

Figure 2. Shopping Participation Rates by Decision to Participate in an Act129 Program

Figures 3 and 4 show the income and home size distribution of PPL residential shopping customers respectively. Figure 3 shows that the highest rate of shopping (49%) is in the high income category of $100,000 to $149,000. There is not much difference across income levels in the rate of shopping. Figure 4 shows that the shopping rate increases with house size. The highest shopping rate (54%) is for homes that are greater than 5000 square feet in size.

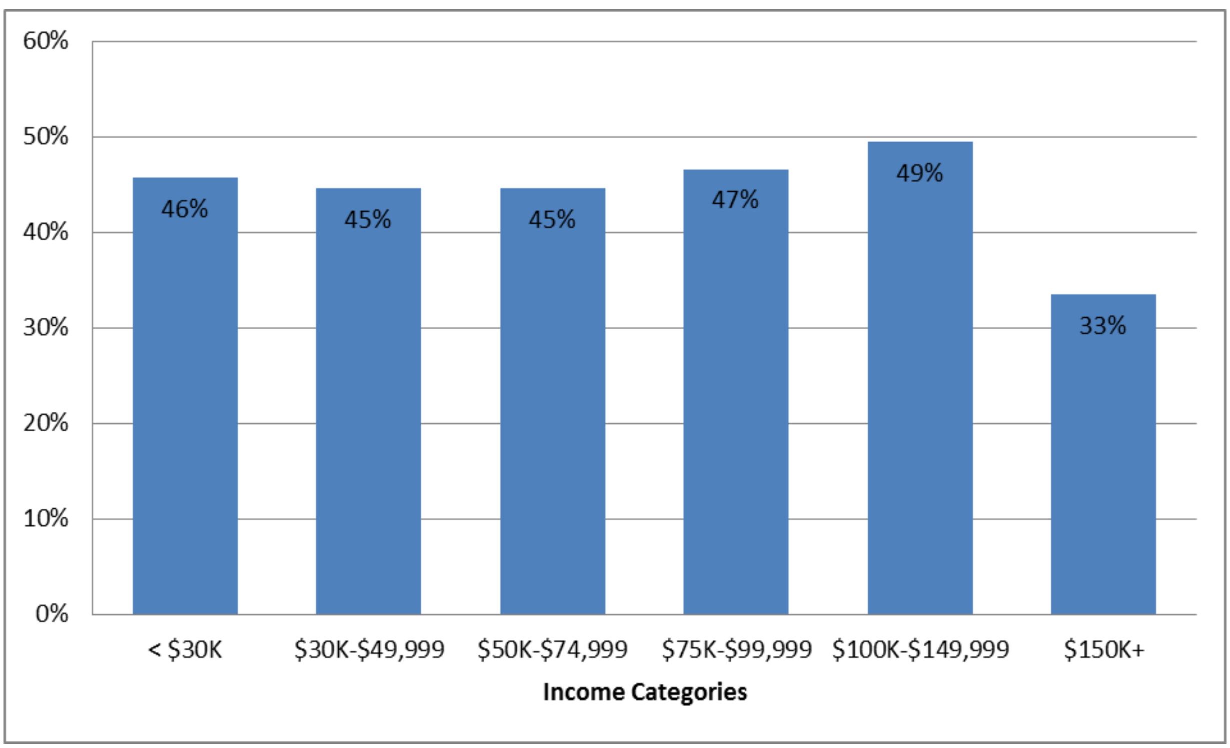

Figure 3. Percentage of PPL Residential Households Shoppers by Income Distribution

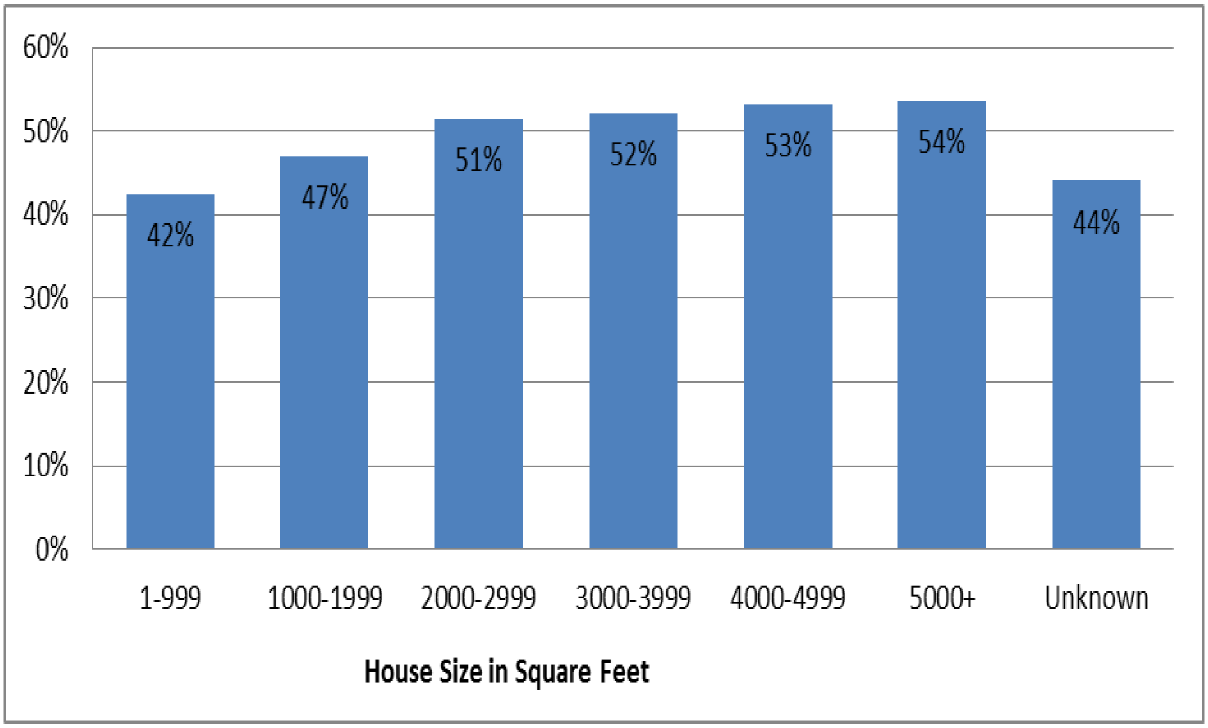

Figure 4. Percentage of PPL Residential Shoppers by Home Size[4]

Discussion of Data Used in the Electricity Demand Model

Table 2 provides the descriptive statistics for the key variables used to predict the electricity usage per customer. The mean Usage per Customer (UPC) from January 2000 to May 2009 (the non-program period) was approximately 958 kWh during which the customers paid a nominal electricity price of 5.08 cents per kWh.

Table 2. Descriptive Statistics (Monthly from January 2000 to May 2009)

Variable	N	Mean	Std Dev	Minimum	Maximum
UPC (kWh)	113	958	201	672	1501
Default or the nominal electricity price (cents per kWh)	113	5.08	0.49	4.33	6.03
Income per capita (Thousand, $)	113	35.02	1.39	33.06	37.73
Heating Degree Days (65)	113	484	415	0	1269
Cooling Degree Days (65)	113	67	97	0	351

[4] This chart applies to only a sub-set of the residential population because house size information is missing for approximately 31% of the customers.

Table 3. Actual Electricity Demand and Nominal Prices by PPL Program Years

Program Year	Program Year Duration	Nominal Default Electric Price	Nominal Shopping Price	Actual UPC for all non shoppers	Actual UPC for all customers	Actual UPC for shoppers
1	Jun 2009 to May 2010*	7.62	9.43	930	940	998
2	Jun 2010 to May 2011	9.96	9.30	922	988	1,118
3	Jun 2011 to May 2012	8.12	8.68	837	920	1,047
4	Jun 2012 to January 2013	7.84	8.07	845	933	1,061

***Shopping begins from January 2010. Hence the shopping price and the UPC for shoppers is average over Jan 2010 to May 2010.**

Table 3 shows the average actual consumption per customer and average prices over the program years. As prices increase, we would expect the demand for electricity to fall. However, this table shows us the actual effect of what happened during the program years in terms of usage per customer. During the four program years we saw the expiration of capped rates, starting of the price competition in the retail electricity markets and implementation of Act 129. We observe the following trends during this period:

1. The average consumption per shopping customer was consistently higher than that of the non-shopping customers, irrespective of the price differential. On average, the shopping customers consume 25% more electricity than the non-shopping consumers, especially in the last two years when shopping price was on average 5% higher. There are several factors that could explain this:
   a. The shopping customers were high consumers to begin with and they self-selected to participate in the retail market.
   b. The shopping customers increased their consumption under the expectation that the prices would decrease due to retail market competition.
   c. The shopping consumers are simply unaware that the shopping prices have in fact been higher than the default price.
2. Even though the nominal shopping price on average decreases by 14% from PY1 to PY2, there is only a 6% increase in the average consumption per shopping customers. However, for the non-shopping customers we see an average price increase of about 3% and a decrease in average consumption of about 9% over the four year period. Again there might be several factors at play here. For example:
   a. It might be the case that in the long run (defined as the four year program period) the shoppers (after they switch to alternative retailers) tend to be less price responsive than the non-shoppers.
   b. It might be due to the fact that price responsiveness is not symmetric, that is with a price increase/decrease the effect on consumption is more/less than otherwise.
3. Specifically with respect to PY2 when the average default prices increased by 31% the non-shoppers decreased their consumption by only 1%. This is because equipment stock cannot adjust easily to the sudden changes in the price. We do see decrease in consumption in the later years when additional savings were also expected from Act 129 participation.

The first hypothesis that the shoppers could be high consumers even when they were not shopping cannot be proved without the use of billing data for the pre-shopping period. Hence, the verification of this hypothesis is beyond the scope of this paper. Similarly, we cannot prove that the shoppers were characteristically (price responsiveness) different from the non-shopping consumers without the use of additional data.

In the next section we formulate a time series model that would come closest to explaining the actual observation with the intention of teasing out the individual and combined effects of shopping and participation in Act 129.

Discussion of the Electricity Demand Model

The data are a utility-level panel of monthly observations that span from Jan 2000 to May 2009 and include residential electricity consumption and prices along with a set of covariates that are assumed to drive consumption.

The following empirical model of residential electricity demand is expressed as a function of electricity prices, weather, economic factors like income and time trend. We formulate a dynamic process since it uses the lag structure of the dependent variable.

$$UPC_t = \beta_0 + \beta_{-1}UPC_{t-1} + \beta_P REP_t + \beta_I IPC_t + \beta_{HDD}HDD_t + \beta_{CDD}CDD_t + \beta_{HDDt}HDD_t * Time\ trend + \beta_{CDDt}CDD_t * Time\ trend + \sum_{i=1}^{11} \beta_i\, Month_i + v_t$$

where UPC_t is the average monthly electricity usage per customer, IPC_t is the income per capita, REP_t is the real average price of electricity (CPI Index 2000 = 100), HDD_t and CDD_t are the heating and cooling degree days in month t and $Month_i$ is the dummy variable for each month *i* from January to November. The HDD and the CDD terms are interacted with the time trend.

It was seen that the actual electricity consumption did not change dramatically with the default price change that occurred after the rate caps expired. This is because equipment stock cannot adjust easily to the sudden changes in the price. Studies have used a partial adjustment mechanism to allow for situations that *require prices to adjust to long-run equilibrium*[5] or to capture the *dynamics of the demand stickiness imposed by the capital-intensive nature of electricity consumption*[6]. Following this mechanism, the model here assumes that the change in the average monthly consumption between two periods' t-1 and t is only a fraction of the difference between the average consumption in the two periods. Other model specification were also formulated, however, the least error as the percentage of actual consumption was obtained with the specification in Equation 1.

The models are estimated using Maximum Likelihood, because the models include a lagged dependent variable and the resulting autocorrelation could bias the coefficient estimates if OLS models were used. The lagged dependent variable controls for a dependent variable that follows an AR(1) process. Since it varies over time, the inclusion of the lagged dependent variable allows isolating what is happening in period t irrespective of what might have happened in t-1.

Discussion of the Results from the Model

Table 4 on next page provides parameter estimates of the model and the model fit. The model is estimated using Maximum Likelihood Estimation. Most of the parameter estimates are statistically significant and the coefficients have the expected signs. The estimated coefficient of the real electricity price

[5] Alberini, A. , Filippini, M. (2011). Response of residential electricity demand to price: The effect of measurement error. Energy Economics 33 (889-895).

[6] Paul A., Myers E. and Palmer K. (2009). A Partial Adjustment Model of U.S. Electricity Demand by Region, Season, and Sector" RFF Discussion Paper 08-50.

is –4169 which is significant at the 90% confidence level, and gives a short-run average price elasticity of -0.1951. The estimated coefficient of the lagged dependent model is positive and significant. Using the lagged dependent variable in the regression can lead to well-known bias when serial correlation is present. We test for autocorrelation in the presence of lagged dependent variable using the Durbin h test. The Durbin h statistic is 0.6556 with a p-value of 0.2560 indicating the absence of auto-correlated error terms.

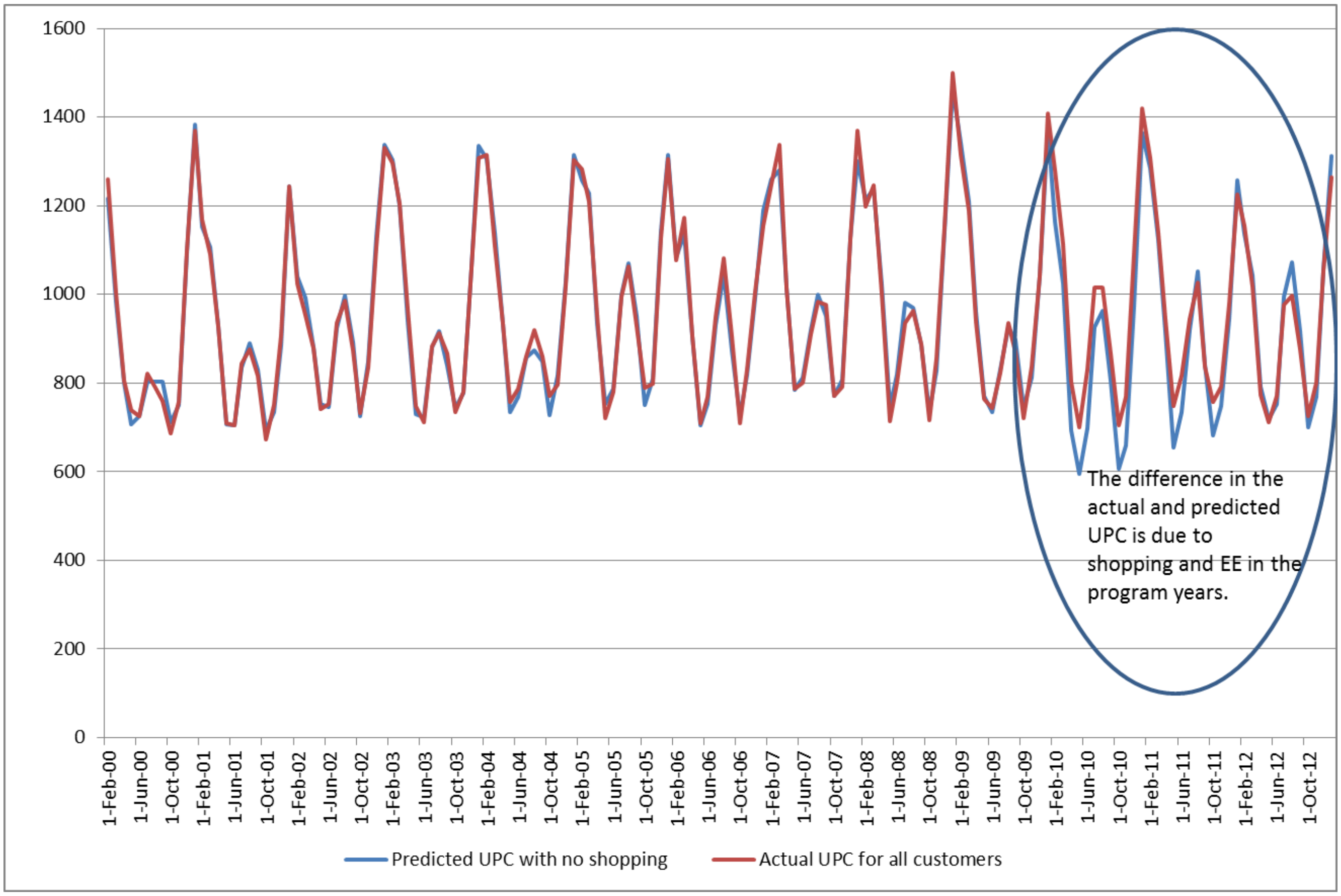

Figure 5: The model fit for the period January 2000 to May 2009

Figure 5 shows the predicted values from the regression model against the observed UPC. The model predicts well for the period January 2000 to May 2009. From June 2009 onwards Act 129 and shopping occurred. For this period the baseline consumption differs from the observed consumption due to the program effects.

Table 4. Estimated Parameters of the Model

Parameter Estimates				
Variable	**Estimate**	**Standard Error**	**t Value**	**p value**
Intercept	470.1187	133.8307	3.51	0.0007
UPC(lag 1) previous period	0.1659	0.0376	4.41	<.0001
Real electricity Price	-4169	2297	-1.82	0.0727
Income per capita	4.0422	3.8579	1.05	0.2974
HDD65	0.5189	0.0326	15.9	<.0001
CDD65	0.7877	0.1341	5.88	<.0001
HDD65*Time trend	0.001099	0.000192	5.72	<.0001
CDD65*Time trend	0.003701	0.001008	3.67	0.0004
Dummy variable for January	65.1369	15.804	4.12	<.0001
Dummy variable for February	-81.2712	22.8914	-3.55	0.0006
Dummy variable for March	-46.7393	19.3524	-2.42	0.0177
Dummy variable for April	-62.0548	19.1634	-3.24	0.0017
Dummy variable for May	-41.5564	20.0433	-2.07	0.0409
Dummy variable for June	44.2195	23.692	1.87	0.0651
Dummy variable for July	98.2819	31.1354	3.16	0.0022
Dummy variable for August	81.9664	33.5732	2.44	0.0165
Dummy variable for September	89.5588	29.2021	3.07	0.0028
Dummy variable for October	4.6013	22.2599	0.21	0.8367
Dummy variable for November	-42.7405	14.8871	-2.87	0.0051

Table 5. Model Results at the Aggregate Program Level

Program Year	Program Year Duration	Total Actual Usage (MWh)	Total Unconstrained Usage (Predicted MWh)	Total Unconstrained Usage plus Shopping Impact (Predicted MWh)	Total Shopping Impact (MWh)	Total Act 129 Impact (MWh)[1]
		(1)	(2)	(3)	(3) - (2)	
1	June 2009 to May 2010	13,798,311	13,193,652	13,243,072	49,420	(61,415)
2	June 2010 to May 2011	14,520,939	13,413,987	13,539,381	125,394	(228,445)
3	June 2011 to May 2012	13,538,330	13,508,190	13,389,003	(119,187)	(366,176)
4	June 2012 to Jan. 2013	9,168,023	9,475,147	9,438,272	(36,875)	(400,781)

[1] Based on PPL Electric's PY 1-3 Final Annual Reports to PA PUC, adjusted for the Residential sector.

In Tables 5 and 6, a discussion of the deviation of baseline from the observed consumption is provided. Table 5 shows the model fit at the aggregate program year level. Program Year 1 (PY1) starts in June 2009 and ends in May 2010 and so on. There is incomplete data in the billing analysis for Program Year 4 due to non-availability of data after January 2013. Total actual usage is the aggregated observed usage by all the PPL residential customers over the program years. The total usage increases by 5.24% from PY1 to PY2 and then decreases by -6.77% from PY2 to PY3.

Total unconstrained usage is the estimated counterfactual or the baseline usage that would have been, had there been no shopping and no Act 129. We use coefficient estimates from Table 4, the default price and the economic and weather variables during the program years, and the total population during the program years to estimate the unconstrained usage. The total unconstrained usage increases from PY1 to PY2 by 1.67%, indicating an increase in baseline consumption without the Act 129 or shopping interventions. However, the unconstrained usage does reflect the fluctuations in the default electricity price due to the expiration of rate caps. The default electricity price increased by more than 30% from PY1 to PY2.

Total usage with shopping is the estimated usage with the shopping effect but not the Act 129 participation effect. It is estimated by taking the sum of the total consumption by non-shoppers and the shoppers. The total consumption of shoppers without Act 129 effect is predicted using the same coefficient estimates in Table 4, the shopping price, the same economic and weather conditions in the program years as in unconstrained usage. We see that the total consumption with shopping increased by 2.24% from PY1 to PY2 when shopping price was lower than the default price and then decreased by 1.11% from PY2 to PY3 when shopping price tended to be higher than the default price. The last column of Table 5 shows the net savings from Residential Act 129 programs, including the upstream Lighting Program.

Table 6 on next page shows the individual and combined impacts of shopping. The immediate effect of allowing customers to shop was to increase the total usage as the shopping prices were initially lower than the default price. However, as the shopping prices became higher than the default prices in PY3 and PY4, the resulting impact was a decline in the usage. Thus the shopping impact reinforced the impact of Act 129 in program years 3 and 4 leading up to a decrease in the total predicted usage. Stated another way, the shopping impacts complement the impacts of Act 129 as long as the prices from shopping remain above the default price. As shown in Table 6, the presence of shopping and Act 129 in PY4 resulted in a 4.62% decline in usage from predicted levels.

Table 6. Impacts of Shopping and Act 129 Energy Efficiency as a Percentage of the Predicted Usage

Program Year	Impact of EE	Impact of shopping	Impact of shopping and EE
1	-0.465%	0.37%	-0.09%
2	-1.703%	0.93%	-0.77%
3	-2.711%	-0.88%	-3.59%
4	-4.230%	-0.39%	-4.62%

Conclusions

Evidence presented in this paper suggests that PPL Electric's residential customers have participated in large numbers in both retail electricity shopping and energy efficiency programs such as Act 129. Also, retail shopping and Act 129 participation are positively correlated with each other. This is a healthy outcome from a regulator's perspective considering both energy efficiency and retail electricity shopping are worthy goals in of themselves. While the impact of Act 129 has been consistently increased energy savings for residential customers, the impact of electricity shopping on consumption has been somewhat mixed. To the degree average shopping price continues to stay higher than the default price, the shopping impacts complement the Act 129 impacts, rather than mitigate them.

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