The Brattle Group

Evaluation of Baltimore Gas and Electric Company's Smart Energy Pricing Program

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Presented by:
Sanem Sergici, Ph.D.
Ahmad Faruqui, Ph.D.

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Agenda

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2. Literature review
3. Research Question
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BGE initiated "Smart Energy Pricing (SEP)" experiment in 2008 to test residential customer responsiveness to dynamic pricing

SEP 2008 tested two dynamic pricing options: critical peak pricing (CPP) and peak time rebate (PTR) tariff

- Treatment period covered June-September 2008 and pre-treatment period covered March-May 2008
- 12 event days were called
- Final sample consisted 1,375 customers of which 1,021 were treatment and 354 were control
- Involved two technologies: Energy Orb and Central Air Conditioning (CAC) Switch

SEP 2009 tested only the peak time rebate (PTR) tariff

- Treatment period covered June-September 2009 and pre-treatment period covered March-May 2009
- 12 event days were called
- Final sample consisted 912 customers of which 734 were treatment and 178 were control
- Involved two technologies: Energy Orb and Smart Thermostat

Rate and Technology Combinations tested in the SEP 2008 and 2009 Pilots

SEP	Group	Rate Design	Enabling Technology	Treatment Group	Control Group	Total
2008	DPP	DPP	None	148	-	148
	DPP_ET_ORB	DPP	Energy Orb and A/C Switch	111	-	111
	PTRL	PTRL	None	126	-	126
	PTRL_ORB	PTRL	Energy Orb Only	141	-	141
	PTRL_ET_ORB	PTRL	Energy Orb and A/C Switch	113	-	113
	PTRH	PTRH	None	127	-	127
	PTRH_ORB	PTRH	Energy Orb Only	137	-	137
	PTRH_ET_ORB	PTRH	Energy Orb and A/C Switch	118	-	118
	Total- SEP 2008	**-**	**-**	**1021**	**354**	**1375**
2009	PTR	PTR	None	268	-	268
	PTR_ORB	PTR	Energy Orb Only	107	-	107
	PTR_ET_ORB	PTR	Smart Thermostat	282	-	282
	PTR_ET	PTR	Energy Orb and Smart Thermostat	77	-	77
	Total- SEP 2009	**-**	**-**	**734**	**178**	**912**

All-in rates for the treatments are presented below

SEP	Pilot	Original	Critical	Peak	Offpeak
2008	DPP	0.153	1.309	0.149	0.099
	DPP_ET_ORB	0.153	1.309	0.149	0.099
	PTRL	0.153	1.313	0.153	0.153
	PTRL_ORB	0.153	1.313	0.153	0.153
	PTRL_ET_ORB	0.153	1.313	0.153	0.153
	PTRH	0.153	1.903	0.153	0.153
	PTRH_ORB	0.153	1.903	0.153	0.153
	PTRH_ET_ORB	0.153	1.903	0.153	0.153
2009	PTR	0.164	1.664	0.164	0.164
	PTR_ORB	0.164	1.664	0.164	0.164
	PTR_ET_ORB	0.164	1.664	0.164	0.164
	PTR_ET	0.164	1.664	0.164	0.164

Notes:
1- All rates are presented in all-in terms. They include generation, transmission, distribution, and customer charges.
2- Rebate levels for PTRL, PTRH, and PTR are $1.16/kWh, $1.75/kWh, and $1.5/kWh respectively.

Time-based pricing has been extensively researched

Caves et al. (1984) reviewed the data from five residential time-of-use (TOU) pricing experiments

Aubin et al (1995) examined the impacts of Electricite de France's (EdF) Tempo tariff

Braithwait (2000) investigated the impacts of a residential TOU program using a constant elasticity of substitution model

Taylor et al. (2005) estimated hourly elasticities for Duke Power's industrial customers on RTP rates

SEP participants reduced their usages in the range of 18 to 33 percent in 2008. Does this impact persist?

Impact evaluation of the SEP 2008 revealed that:

- Customers w/o technologies reduced their peak demand in the range of 18 to 21 percent
- When Energy Orb was paired with prices, the reductions were in the range of 23 to 27 percent
- When the CAC switch was activated in addition to the Orb, the impact ranged from 29 to 33 percent

<u>Question</u>: Is there a persistency in customers' price responsiveness or do these impacts represent a one time novelty ?

During the SEP 2008 and 2009, BGE collected hourly electricity usage data on treatment and control customers

Hourly electricity consumption data on all treatment and control customers for March-September 2008 and March-September 2009 periods

- We identified the group of customers who participated in both years resulting in a sample of 657 treatment and 178 control customers

Hourly temperature and dew point data for the analysis period

All-in rate information for all customers and dates

We estimated a constant elasticity of substitution (CES) model to obtain customers' electricity demand parameters

CES model is consistent with the theory of utility maximization and allows elasticity of substitution to take on any value

- CES is more flexible than Cobb-Douglas model which imposes a unitary elasticity of substitution
- There are more flexible functional forms such as Trans-log, Generalized Leontief, and Generalized McFadden, but this flexibility comes at the expense of ease of computation and interpretation

For a two-period rate structure, CES model consists of two equations

1. Substitution equation to predict the change in load shape caused by changing peak-to-off peak prices

- Percent change in the ratio of peak to off-peak consumption when there is one percent change in the ratio of peak to off-peak prices

2. Daily (price) equation to predict the change in daily energy consumption caused by changing daily prices

- Percent change in the daily average consumption when there is one percent change in the daily average price

We employed the fixed-effects estimation routine to estimate the demand system

Substitution Equation Specification

$$\ln\left(\frac{Peak\_kWh}{OffPeak\_kWh}\right)_{it} = \alpha_0 + \alpha_1 THI\_DIFF_{it} + \alpha_2 \ln\left(\frac{Peak\_Price}{OffPeak\_Price}\right)_{it} + \alpha_3 \ln\left(\frac{Peak\_Price}{OffPeak\_Price}\right)_{it} xTHI\_DIFF_{it}$$
$$+ \sum_{k=1}^{6} \delta_k (THI\_DIFFxD\_Month_k)_{it} + \alpha_4 D\_TreatPeriod_t + \alpha_5 D\_TreatPeriodxTreatCustomer_{it}$$
$$+ \sum_{k=1}^{6} \beta_k D\_Month_k + \sum_{k=1}^{12} \gamma_k D\_CPP_k + \alpha_6 D\_WEEKEND + v_i + u_{it}$$

$\ln\left(\frac{Peak\_kWh}{OffPeak\_kWh}\right)$: Logarithm of the ratio of peak to off-peak load for a given day

THI_DIFF :The difference between peak and off-peak THI. THI is defined as follows:

THI= 0.55 x Drybulb Temperature + 0.20 x Dewpoint + 17.5

$\ln\left(\frac{Peak\_Price}{OffPeak\_Price}\right)$:Logarithm of the ratio of peak to off-peak prices for a given day

$\ln\left(\frac{Peak\_Price}{OffPeak\_Price}\right)xTHI\_DIFF_{it}$:Interaction of ratio of peak to off-peak prices and THI_DIFF for a given day

THI_DIFFxD_Month :Interaction of THI_DIFF variable with monthly dummies

$D\_TreatPeriod$:Dummy variable is equal to 1 when the period is June 2008 through September 30, 2008

$D\_TreatPeriodxTreatCustomer$: Interaction of $D\_TreatPeriod$ with treatment customer dummy

D_Month_k : Dummy variable that is equal to 1 when the month is k

D_CPP : Dummy variable that is equal to 1 on CPP days

$D\_WEEKEND$: Dummy variable that is equal to 1 on weekends

Daily Demand Equation Specification

$$\ln(kWh)_{it} = \alpha_0 + \alpha_1 \ln(THI)_{it} + \alpha_2 \ln(\text{Pr}\, ice)_{it} + \alpha_3 \ln(\text{Pr}\, ice)_{it}\, x \ln(THI)_{it} + \sum_{k=1}^{6} \delta_k (\ln(THI)\, xD\_Month_k)_{it}$$
$$+ \alpha_4 D\_TreatPerio\, d_t + \alpha_5 D\_TreatPerio\, dxTreatCus\, tomer_{it} + \sum_{k=1}^{6} \beta_k D\_Month_k + \sum_{k=1}^{12} \gamma_k D\_CPP_k$$
$$+ \alpha_6 D\_WEEKEND + v_i + u_{it}$$

$\ln(kWh)$	: Logarithm of the daily average of the hourly load
$\ln(THI)$	: Logarithm of the daily average of the hourly THI
$\ln(\text{Pr}\, ice)$	: Logarithm of the daily average of the hourly Price
$\ln(\text{Pr}\, ice)\, x \ln(THI)$	: Interaction of price with ln (THI)
$\ln(THI)\, xD\_Month$	: Interaction of $\ln(THI)$ variable with monthly dummies
$D\_TreatPeriod$	: Dummy variable is equal to 1 when the period is June 2008 through September 30, 2008
$D\_TreatPeriodxTreatCustomer$	: Interaction of $D\_TreatPeriod$ with treatment customer dummy
D_Month_k	: Dummy variable that is equal to 1 when the month is k
D_CPP	: Dummy variable that is equal to 1 on CPP days
$D\_WEEKEND$	: Dummy variable that is equal to 1 on weekends

Pooled Model Estimation Results

Substitution Equation- Pooled Model

Dependent Variable: ln (peak_kwh/offpeak_kwh)	
ln_price_ratioxthi_diff	-0.017**
	(0.000)
ln_price_ratioxthi_diffx2009	-0.006**
	(0.006)
ln_price_ratioxORBxthi_diff	-0.006**
	(0.008)
ln_price_ratioxORBxthi_diffx09	-0.002
	(0.603)
ln_price_ratioxORB_TECHxthi_diff	-0.012**
	(0.000)
ln_price_ratioxORB_TECHxthi_diffx09	0.002
	(0.324)
Observations	294303
R-squared	0.114
Number of customerid	835

Robust p-values in parentheses
** p<0.01, * p<0.05

Daily Equation- Pooled Model

Dependent Variable: ln (average_daily_consumption)	
ln_pricexln_thi	-0.009**
	(0.000)
ln_pricexln_thix2009	-0.004
	(0.053)
Observations	293973
R-squared	0.101
Number of customerid	835

Robust p-values in parentheses
** p<0.01, * p<0.05

Full estimation results can be found in the paper.

Results show that the customers' price responsiveness persist in the second year of the pilot

Substitution Elasticity Comparison: SEP 2008 vs SEP 2009

Elasticity	SEP 2008 (thi_diff= 6.65)	SEP 2009 (thi_diff= 5.25)	SEP 2009 (thi_diff= 6.65)
Price only	-0.096	-0.121	-0.153
Price+ORB	-0.136	-0.152	-0.193
Price+ORB+TECH	-0.180	-0.184	-0.233

Note: Average SEP 2008 thi_diff=6.65 and Average SEP 2009 thi_diff=5.25

- SEP 2009 substitution elasticities are higher than those of the SEP 2008

Daily Elasticity Comparison: SEP 2008 vs SEP 2009

Elasticity	SEP 2008 (ln_thi= 4.31)	SEP 2009 (ln_thi= 4.31)
Daily	-0.039	-0.039

Note: Average SEP 2008 ln_thi=4.31 and Average SEP 2009 ln_thi=4.31

- SEP 2009 daily elasticity is equal to that of the SEP 2008

We solve the demand system simultaneously to calculate the peak demand impacts

In 2008, we find that peak demand impacts are in the range of 18 to 33 percent

Although the customers were more price elastic in 2009, the rebate level was less than that in 2008. Resulting peak impacts are in the range of 23 to 31 percent

SEP	Rate	Price only	Price + ORB	Price + ORB + ET
2008	DPP	20.1%	-	32.5%
2008	PTRL	17.8%	23.0%	28.5%
2008	PTRH	21.0%	26.8%	33.0%
2009	PTR	22.6%	26.9%	31.0%

Conclusions

We pooled SEP 2008 and 2009 pilot datasets to investigate the persistence of customer price responsiveness

- We found that BGE SEP customers were persistent in their price responsiveness in the 2nd year of the program despite milder summer conditions
- In fact, SEP customers increased their elasticities suggesting that learning and adaptation were taking place

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sanem.sergici@brattle.com
44 Brattle Street
Cambridge, MA 02138