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Consistency of Results in Dynamic Pricing Experiments

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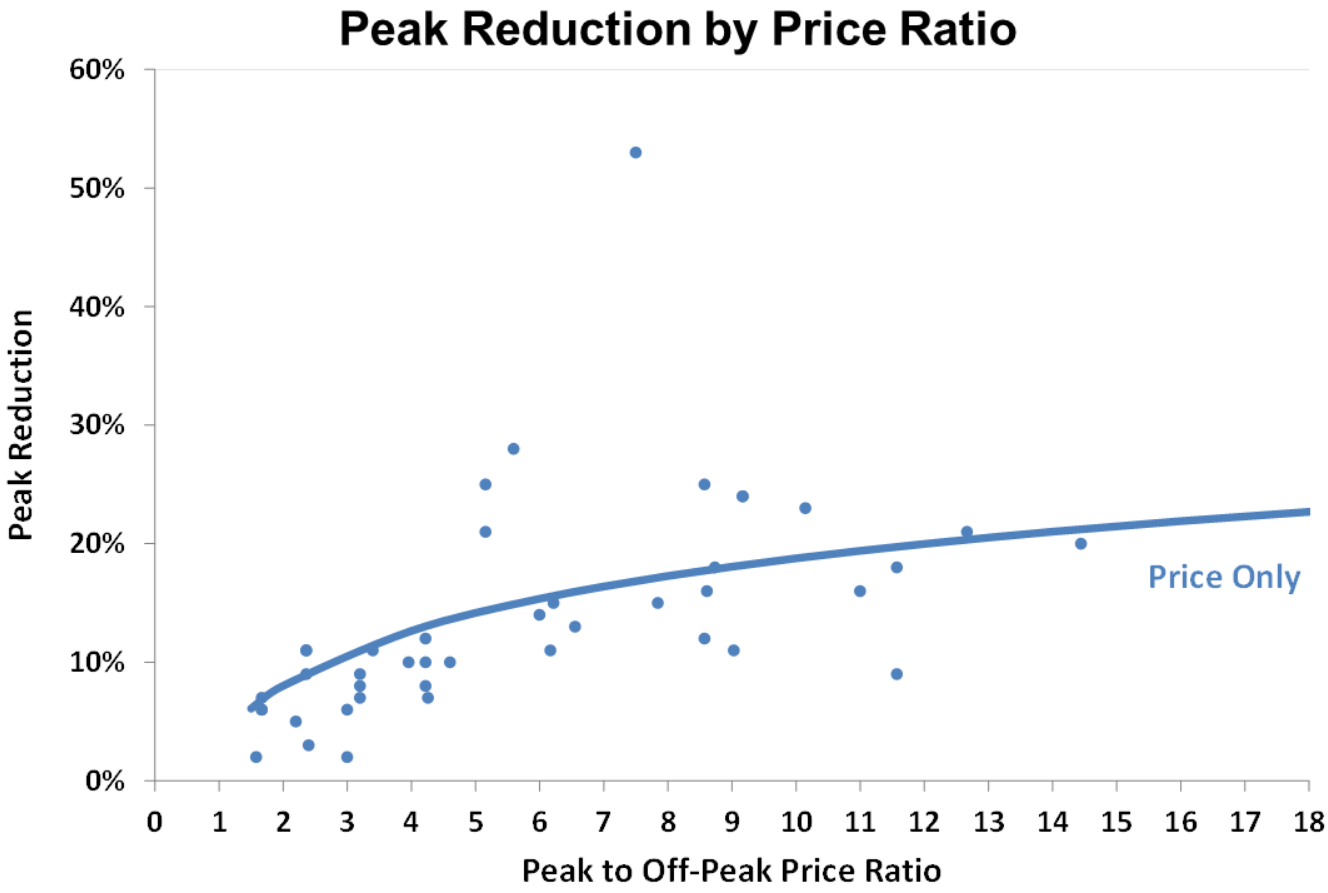
Demand is price responsive



Price responsiveness is estimated from more than two dozen dynamic pricing pilots undertaken in the last decade. These have yielded upwards of 120 treatments spread across three continents

But does price-responsiveness persist over time?

Most scientifically-designed pricing pilots last just one season

Baltimore Gas & Electric Company (BGE) ran a scientifically designed experiment for 4 years

We estimate a Constant Elasticity of Substitution (CES) model for each of the years individually and collectively

- We find
  - Reponses persist across all 4 summers

The Baltimore Gas & Electric Company Experiment

The BGE Experiment

Continued for 4 consecutive summers

Nearly 950 participants at its peak

More than 11 different treatments

- Price only treatment offered across all years

Scientifically sound design

- Pre-treatment and treatment periods
- Control group
  - But differential selection between treatment and control
  - Accounted for in regression models

Many Treatments over Time

	2008	2009	2010	2011
Peak Time Rebate (Price Only)	X	X	X	X
Peak Time Rebate + Energy Orb	X	X		
Peak Time Rebate + Energy Orb + AC Switch	X			
Peak Time Rebate + Energy Orb + Smart Thermostat		X		
Peak Time Rebate + Smart Thermostat		X		
Dynamic Peak Price (DPP)*	X			
Peak Time Rebate + Change in Notification Period			X	X
Peak Time Rebate + Change in Event Window				X
Peak Time Rebate + In Home Display/Portal			X	X
Peak Time Rebate + Legacy DLC Program				X
Legacy DLC Program				X
Control Group	X	X	X	X

* DPP = CPP + TOU. This was also combined with an Energy Orb and AC Switch

PTR Events

Events were called in Summer from 2pm-7pm

Customers notified the day before at 6pm

	2008	2009	2010	2011
Number of events	12	12	14	4
Peak to Off-Peak Price Ratio	9 & 12.5	10	9	10

Off peak rate was calculated as the average of standard all-in rate

Experimental Design

Control group selected randomly from load research sample

- Not informed of study

Treatment group recruited randomly and paid $100 at the end of the pilot as an appreciation for staying in it

- Differences between treatment and control customers that do not change over time are accounted for using individual level "fixed effects"

Pre-treatment period March-May

Treatment Period June-September

	2008	2009	2010	2011
Number in PTR Only Treatment	253	268	138	235
Number in Control	354	178	169	140

Results of Persistence Analysis

Methodology

We pooled data across all fours years and estimated year-specific coefficients

This allows us to test whether impacts for any year are statistically different from any other year

All impacts were analyzed using a Constant Elasticity of Substitution (CES) Model

We estimated substitution and daily price elasticities

Substitution and daily price elasticities are estimated to represent the price responsiveness of the pilot participants

The substitution elasticity measures 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

The daily (price) elasticity measures 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

Model Specification

Substitution Equation

$$\ln\left(\frac{Peak\_kWh}{OffPeak\_kWh}\right)_{it} = \alpha_0 + \alpha_1 THI\_DIFF_{it} + \sum_{k=4}^{7} \delta_k (THI\_DIFFxD\_Month_k)_{it} + \alpha_3 D\_TreatPeriod_t + \alpha_4 TreatCustomer +$$
$$\alpha_5 D\_TreatPeriodxTreatCustomer_{it} + \alpha_6 \ln\left(\frac{Peak\_Price}{OffPeak\_Price}\right)_{it} xTHI\_DIFF_{it} +$$
$$\sum_{k=1}^{8} \beta_k D\_CPP\_Day_k + \sum_{k=4}^{7} \beta_k D\_Month_k + \alpha_9 D\_WEEKEND + v_i + u_{it}$$

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

THI_DIFF_{it} : 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

THI_DIFFxD_Month : Interaction of *THI_DIFF* variable with monthly dummies

$D\_TreatPeriod$: Dummy variable is equal to 1 from June 2011 to September 30, 2011

$TreatCustomer$: Dummy variable is equal to 1 for a treatment customer

$D\_TreatPeriodxTreatCustomer$: Interaction of *D_TreatPeriod* with treatment customer dummy

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

$D\_CPP\_Day_k$: Dummy variable that is equal to 1 on an event day

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

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

Model Specification

Daily Equation

$$\ln(daily\_kWh)_{it} = \alpha_0 + \alpha_1 \ln(THI_{it}) + \sum_{k=4}^{7} \delta_k (\ln(THI) xD\_Month_k)_{it} + \alpha_3 D\_TreatPeriod_t + \alpha_4 TreatCustomer +$$
$$\alpha_5 D\_TreatPeriodxTreatCustomer_{it} + \alpha_6 \ln(price)_{it}\, x \ln(THI)_{it} +$$
$$\sum_{k=1}^{8} \beta_k D\_CPP\_Day_k + \sum_{k=4}^{7} \beta_k D\_Month_k + \alpha_9 D\_WEEKEND + v_i + u_{it}$$

$\ln(price)_{it}$	: Logarithm of the price for a given day
$\ln(THI)_{it}$	: Logarithm of THI for a given day
$\ln(THI) xD\_Month$	: Interaction of *ln(THI)* variable with monthly dummies
$D\_TreatPeriod$	: Dummy variable is equal to 1 from June 2011 to September 30, 2011
$TreatCustomer$	: Dummy variable is equal to 1 for a treatment customer
$D\_TreatPeriodxTreatCustomer$	: Interaction of *D_TreatPeriod* with treatment customer dummy
$\ln(price) x \ln(THI)_{it}$	: Interaction of *ln(price)* and *ln(THI)* for a given day
$D\_CPP\_Day_k$	: Dummy variable that is equal to 1 on an event day
D_Month_k	: Dummy variable that is equal to 1 when the month is k
$D\_WEEKEND$	: Dummy variable that is equal to 1 on weekends

How to interpret the results?- I

- **Column A** reproduces the results from the 2010 persistence analysis

- **Column B** allows the comparison of the 2011 impacts for all Price Only customers **to** 2008 through 2010 impacts for those Price Only customers who participated in the pilot for at least the first three years

- **Column C** allows the comparison of the 2011 impacts **to** 2008 through 2010 year impacts for those Price Only customers who participated in the pilot for all four years

How to interpret the results?- II

In each column:

- Orange row represents the 2008 elasticity parameter
- Blue row represents the incremental impact of 2009 above and beyond the 2008 elasticity parameter
- Purple row represents the incremental impact of 2010 above and beyond the 2008 elasticity parameter
- Green row represents the incremental impact of 2011 above and beyond the 2008 elasticity parameter

The model estimation results –
Substitution Equation

Substitution Equation

Dependent Variable: ln (peak_kwh/offpeak_kwh)

VARIABLES	A	B	C
ln_price_ratioxthi_diff	-0.017**	-0.017**	-0.019**
	(0.000)	(0.000)	(0.000)
ln_price_ratioxthi_diffx2009	-0.005*	-0.005*	-0.004
	(0.029)	(0.035)	(0.076)
ln_price_ratioxthi_diffx2010	-0.004*	-0.004*	-0.004
	(0.035)	(0.036)	(0.086)
ln_price_ratioxthi_diffx2011		-0.002	0.002
		(0.468)	(0.530)
Constant	-0.018	-0.070**	-0.052**
	(0.799)	(0.007)	(0.006)
Observations	253,367	339,737	296,398
R-squared	0.115	0.113	0.109
Number of customerid	476	494	406

Robust pval in parentheses
** p<0.01, * p<0.05

Notes:
- Other variables are also controlled for but are not shown here due to space limitations
- Column A reproduces the results from the 2010 persistence analysis
- Column B allows a comparison of the intersection customers in SEP 2008 to SEP 2010, and all customers in SEP 2011
- Column C allows a comparison of the intersection customers that participated in all SEPs

The model estimation results –
Daily Equation

Daily Equation

Dependent Variable: ln (average_daily_consumption)

VARIABLES	A	B	C
ln_pricexln_thi	-0.010**	-0.011**	-0.013**
	(0.000)	(0.000)	(0.000)
ln_pricexln_thix2009	-0.002	-0.002	-0.001
	(0.309)	(0.344)	(0.586)
ln_pricexln_thix2010	0.002	0.002	0.004
	(0.388)	(0.359)	(0.190)
ln_pricexln_thix2011		-0.000	0.005
		(0.965)	(0.195)
Constant	-0.209**	-0.114**	-0.080**
	(0.000)	(0.000)	(0.000)
Observations	253,257	339,899	296,587
R-squared	0.112	0.103	0.102
Number of customerid	476	494	406
rho	0.675	0.694	0.693

Robust pval in parentheses
** p<0.01, * p<0.05

Notes:
- Other variables are also controlled for but are not shown here due to space limitations
- Column A reproduces the results from the 2010 persistence analysis
- Column B allows a comparison of the intersection customers in SEP 2008 to SEP 2010, and all customers in SEP 2011 while restricting SEP 2011 to DA 2-7pm Event Days
- Column C allows a comparison of the intersection customers that participated in all SEPs while restricting SEP 2011 to DA 2-7pm Event Days

Price Only participants of the pilot for four consecutive years *showed persistence* in their price responsiveness behavior

In Column C of the substitution equation, the incremental 2011 impact above and beyond the 2008 impact (ln_price_ratioxthi_diffx2011") is statistically insignificant

- This implies that these customers were as price-responsive in 2011 as they were in 2008, 2009, and 2010

In Column C of the daily equation, the incremental 2011 impact above and beyond the 2008 impact (ln_pricexln_thix2011") is insignificant

- This implies that the customers were as responsive in 2011 as they were in 2008, 2009 and 2010

The substitution and daily elasticities are evaluated at 2008, 2009, 2010 and 2011 weather conditions

SEP 2008/2011

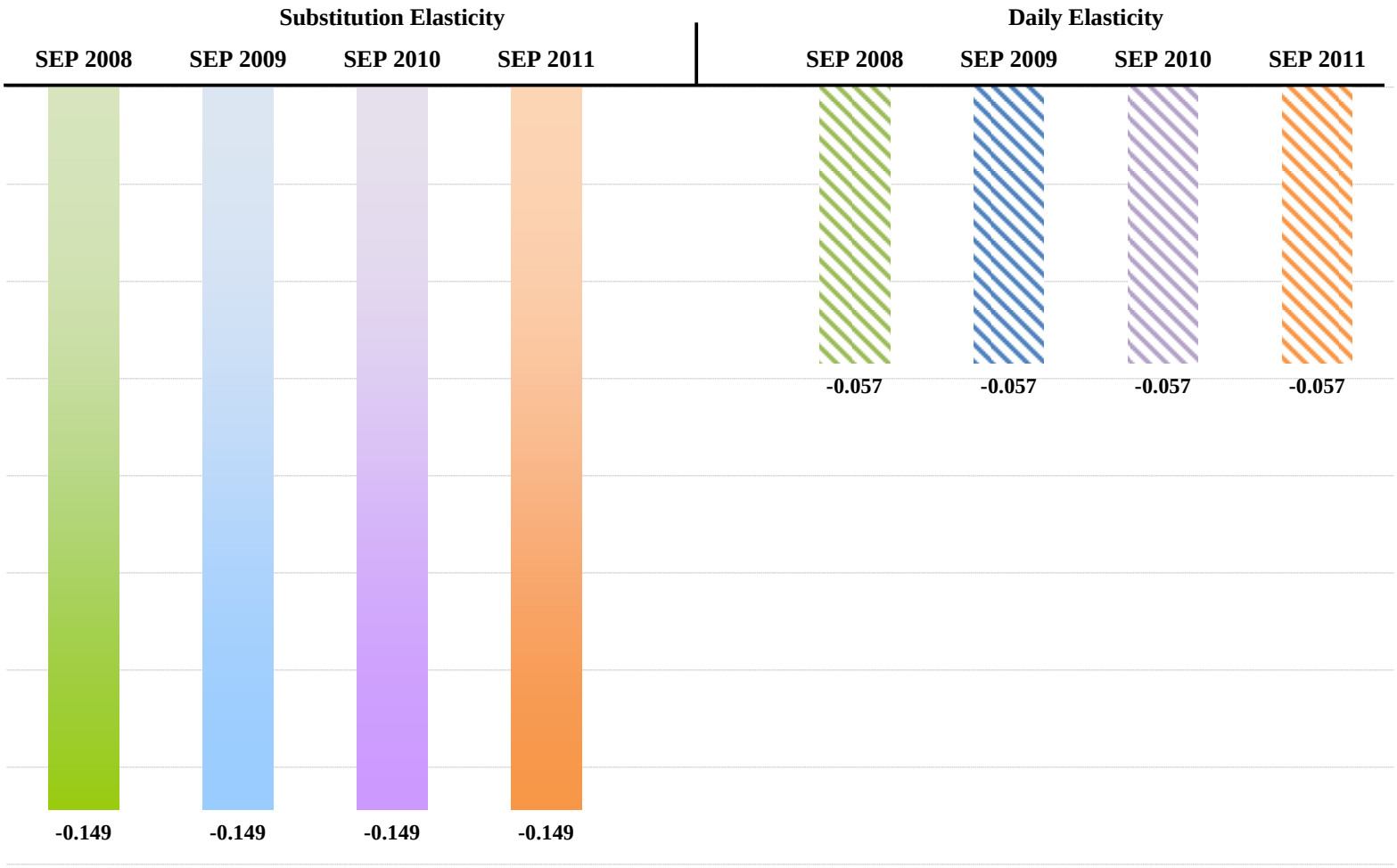
SUBSTITUTION ELASTICITIES				
	2008	**2009**	**2010**	**2011**
Weather - 2008 (THI_DIFF = 6.65)	-0.126	-0.126	-0.126	-0.126
Weather - 2009 (THI_DIFF = 5.25)	-0.100	-0.100	-0.100	-0.100
Weather - 2010 (THI_DIFF = 6.63)	-0.126	-0.126	-0.126	-0.126
Weather - 2011 (THI_DIFF = 7.82)	-0.149	-0.149	-0.149	-0.149

DAILY ELASTICITIES				
	2008	**2009**	**2010**	**2011**
Weather - 2008 (LN_THI = 4.31)	-0.056	-0.056	-0.056	-0.056
Weather - 2009 (LN_THI = 4.31)	-0.056	-0.056	-0.056	-0.056
Weather - 2010 (LN_THI = 4.34)	-0.056	-0.056	-0.056	-0.056
Weather - 2010 (LN_THI = 4.37)	-0.057	-0.057	-0.057	-0.057

Notes:

SEP 2008/2011 analysis uses the price only customers who participated in the pilot for four consecutive years

Substitution and daily elasticities –
SEP 2008/2011 (evaluated at 2011 weather)



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Conclusions

BGE ran CPP events with no enabling technology for four consecutive years

We estimated a Constant Elasticity of Substitution (CES) model, pooling the data across all four years

We find an elasticity of substitution of -0.149

This result is consistent across all four years

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Ahmad Faruqui is a principal with *The Brattle Group* who specializes in the analysis, design and evaluation of smart grid strategies involving the consumer. He has **consulted with more than 50** utilities and transmission system operators around the globe and testified or appeared before a dozen state and provincial commissions and legislative bodies in the United States and Canada. He has also advised the Alberta Utilities Commission, the Edison Electric Institute, the Electric Power Research Institute, the Federal Energy Regulatory Commission, the Institute for Electric Efficiency, the Ontario Energy Board, the Saudi Electricity and Co-Generation Regulatory Authority, and the World Bank. His work has been cited in publications such as The Economist, The New York Times, and USA Today and he has appeared on Fox News and National Public Radio. The author, co-author or editor of four books and more than 150 articles, papers and reports on efficient energy use, he holds a Ph.D. in economics and an M.A. in agricultural economics from The University of California at Davis, where he was a Regents Fellow, and B.A. and M.A. degrees in economics from The University of Karachi with the highest honors.

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Dr. Sanem Sergici is a Senior Associate in *The Brattle Group's* Cambridge, MA office with expertise in electricity markets, applied econometrics, and industrial organization. At *Brattle*, the focus of Dr. Sergici's work has been on assisting electric utilities, regulators, and wholesale market operators in their strategic questions related to energy efficiency, demand response, and customer behavior in the context of Smart Grid. Dr. Sergici has significant expertise in the design and evaluation of dynamic pricing pilot programs; development of load forecasting models; ratemaking for electric utilities; and energy litigation. Her most recent engagements include assisting the utilities in Michigan, Connecticut, Illinois and Maryland in the design and impact evaluation of their pricing and technology pilots. She has spoken at several industry conferences and published in several industry journals.

Dr. Sergici received her Ph.D. in Applied Economics from Northeastern University in the fields of applied econometrics and industrial organization. Her Ph.D. dissertation investigated three important aspects of U.S. electricity restructuring, namely divestures of generation, ISO/RTO formation, and the utility merger wave. She received her M.A. in Economics from Northeastern University, and B.S. in Economics from Middle East Technical University (METU), Ankara, Turkey.

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Neil Lessem is an associate with *The Brattle Group* with expertise in electricity demand response, applied microeconomics, and behavioral economics. He has consulted to utilities, policymakers and technology firms on dynamic pricing, experimental design and policy impact measurement and verification. In his graduate studies he conducted extensive research examining consumer adoption of environmentally friendly products and conservation behaviors, utilizing both field experiments and utility data. Dr. Lessem holds a Ph.D. and M.A. in economics form the University of California – Los Angeles and a B.Bus.Sc in economics and history, from the University of Cape Town, where he graduated with top honors.