An Experimental Comparison of Critical Peak and Hourly Pricing

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Outline of Talk

- Describe mismatch between traditional approach to retail pricing and efficient wholesale market operation
  - Symmetric treatment of load and generation
- Assess performance of popular dynamic pricing programs in US
  - Hourly pricing (HP), critical peak pricing (CPP), CPP with rebate
- DCPowerCents experiment
  - Customer groups and treatments applied
- Measurement framework employed
  - Nonparametric treatment effects
- Empirical results
  - Large treatment effects relative to previous work
    - Higher for All-Electric customers
  - Option to quit is important
  - Cost of taking action does not appear to be important
  - Information provision and automatic response technology economically important

Symmetric Treatment of Consumers and Producers

- In all markets, default price all consumers must pay and producers must receive is real-time price
  - Neither is required to pay or receive this price, but in order to avoid it, market participant must sign hedging arrangement
- Example from airline industry
  - Customers always have option to show up at airport and purchase ticket for flight they would like to travel on at real-time price
  - This purchase strategy has significant price risk because flight can sell out
  - To hedge risk, consumer purchases ticket in advance (fixed-price forward contract)

Symmetric Treatment of Consumers and Producers

- Because of legacy of vertically integrated-monopoly market structure, in many jurisdictions customers have a “free hedge” against real-time price risk through a fixed retail price (schedule) for all consumption
  - In vertically-integrated monopoly regime, utility provided spot electricity price insurance to customer
    - Customer paid firm’s average cost for each KWh consumed and utility ensured supply was always available
- In wholesale market regime it is very difficult to set a fixed retail price that is guaranteed to always cover wholesale energy costs all possible consumption levels

Symmetric Treatment of Load and Generation

- No customer needs to pay real-time price, but all customers need to face risk of real-time price just as generation unit owner does
  - Real-time price risk exists and someone must manage it
  - Putting all real-time price risk on suppliers and retailers is unlikely to be least-cost solution
- Customers can select plan that assumes desired level risk, but they must pay appropriate price for hedge and against real-time price and quantity risk they receive
- Research Question---What should these pricing plans look like?

Dimensions of Dynamic Pricing Plans

- Hourly pricing (HP)--Pass through hourly wholesale price in default retail rate
  - Customer manages all hourly wholesale price risk
  - High cost of taking action could limit size of demand response
- Critical peak pricing
  - Addresses cost of taking action by committing to sustained period of high prices with advance warning
  - Moral hazard problem with retailer declaring CPP days
- Critical peak pricing with rebate
  - Addresses cost of taking action and moral hazard problem
  - Has "option to give up" problem
- Information provision and demand response
  - Smart thermostats

Politically Acceptable Dynamic Pricing

- Major complaint with implementing hourly retail pricing is that customers cannot respond to hourly wholesale prices
  - Difficult to determine when is best time to take action
- If taking action is costly and price increase is for one hour in duration, a very large price spike is needed to cause most customers to respond
  - For residential customer with (2.5 KW) flat load shape, a large price spike is needed to overcome $5 cost of taking action to reduce demand by 20 percent
    - $10,000/MWh for a 0.5 KWh demand reduction for 1 hour
  - Longer duration of high prices requires smaller increase in prices
    - $5,000/MWh average price for 0.5 KWh demand reduction for 2 hours
- Mechanisms that address cost-of-taking-action problem can result in more customers taking on real-time price risk
  - Critical Peak Pricing (CPP) is a popular way to do this

Politically Acceptable Dynamic Pricing

- Critical Peak Pricing—Customer consumes according to usual fixed-price tariff or increasing block fixed-price tariff during all hours of each day
- Customers face risk of Critical Peak Pricing (CPP) day
  - Retailer commits to no more than N (N ≈ 10) CPP days in a pre-specified time interval
  - During peak-period of a CPP day, customer pays a much higher price for all energy consumed during peak period
    - Strong incentive reduce demand during this time period
    - Peak period is typically 4 to 6 hours during day
    - *Addresses cost of taking action problem by committing to a sustained period of high prices*
- Potential moral hazard problem for retailer
  - Can declare CPP day to manage short-term wholesale energy purchase costs due to inadequate forward market procurement
  - Little incentive for retailer not to use all N CPP days because these are high profit days for retailer
    - CPP price much higher than average retail price

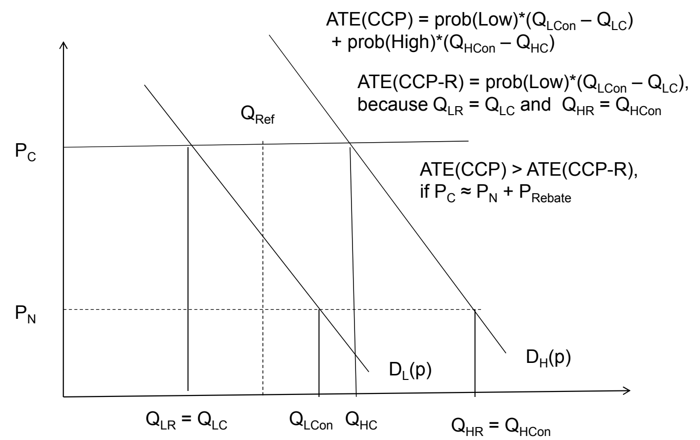
Politically Acceptable Dynamic Pricing

- CPP with rebate is more popular with consumers because it addresses this moral hazard problem
  - During peak hours of CPP days customer receives rebate relative to reference a level consumption, only if its actual consumption is less than reference consumption
  - Retailer faces risk that total rebates paid will be more than wholesale energy procurement cost savings
    - If CPP period wholesale price is $300/MWh (implicit in retail price), then if wholesale price is below $300/MWh, retailer loses money paying for rebate
    - Retailer only wants to declare CPP days when rebates paid are less than wholesale cost savings

Politically Acceptable Dynamic Pricing

- CPP with rebate (CPP-R) implies that customers *guaranteed not to pay more* than they would have under baseline tariff
    - "You can't lose from rebate mechanism"
- Customers have *the option to quit* with no cost implications if it is too difficult to reduce their consumption
  - Pay for consumption above reference level during CPP period at fixed retail price
- Under CPP-R, marginal price of fixed retail price plus rebate is only relevant if consumption is less than reference level
  - Only carrot of rebate is used under CPP-R
- Under CPP, both carrot and stick used
  - Higher price for all consumption during CPP period

Option to Quit and Average Treatment Effect



Research Questions

- Do customers respond to high real-time price warnings and CPP events?
  - Treatment effect of discrete event (price elasticities will come later)
- How do these price responses differ across customer classes?
  - Regular versus all electric customers
  - Low-income versus regular customers
  - Summer versus winter
- Does "cost of taking action" limit demand response of HP customers versus CPP customers?
- Does "option to quit" result in CPP response greater than CRR with rebate (CPP-R) response?
- Do Smart thermostats boost demand response?

PowerCentsDC Program Overview

- Residential pricing pilot in District of Columbia
  - Interval meters to record hourly consumption
  - Hourly pricing (HP)
  - Critical Peak Pricing (CPP)
  - Critical Peak Pricing with Rebate (CPR)
- Governed by "Smart Meter Pricing Pilot, Inc." (SMPPI)
  - Public Service Commission, DC
  - DC Office of People's Counsel
  - Consumer Utility Board
  - IBEW
    - International Brotherhood of Electrical Workers
  - Pepco (contributed $2 million from shareholder funds)

⇩ SMPPI is a non-profit organization created through a Merger Settlement agreement and approved by the Commission on May 1, 2002.

Program Participants

Active Participants	By Usage
Rate Code	**Count**
All Electric	215
Not All Electric	642
Total	**857**

Active Participants	By Income Level
Income Level	**Count**
Low-Income	118
Non Low-Income	739
Total	**857**

Active Participants	By Rate Code
Rate Code	**Count**
Control	388
CPP	236
CPR	387
HP	234
Total	**1245**

Customers are from all eight Wards

Four Customer Codes

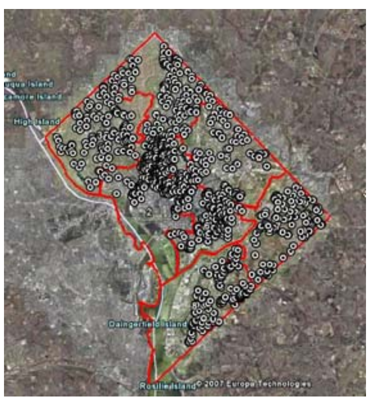
R = Not All Electric

AE = All Electric

RAD = Residential Aid Discount (Low Inc)

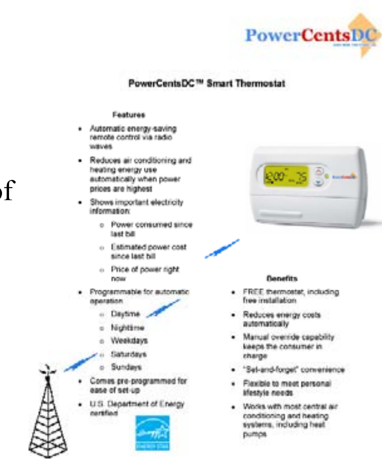
RAD-AE = RAD All Electric (Low Inc)

Location of Participants



Smart Thermostat

- Offered to customers with central A/C and who controlled their thermostat
- Approximately 25% of customers opted for the smart thermostat.
- LED lights up during CPP or High Price event (depending on pricing plan)



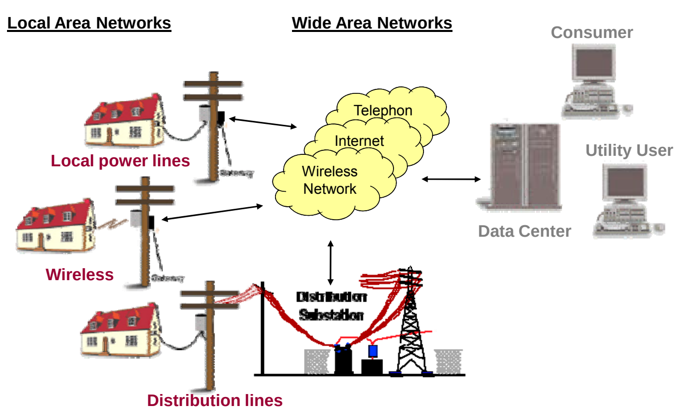
PowerCentsDC Pricing Options

- Critical peak pricing (CPP)
  - A maximum of 12 CPP days during summer and 3 during winter
    - Between 2 pm and 6 pm during summer (4 hours)
    - Between 6 am to 8 am and 6 pm to 8 pm during winter (4 hours)
  - Customers pay according to an increasing block schedule during all other hours
  - Customer charged approximately 75 cents/KWh for energy during CPP period
- Critical peak rebate (CPR)
  - Customer earns rebates during critical peak hours by reducing usage below reference level set by SMPPI
  - Customers pay according to an increasing block schedule during all other hours
  - Customer receives rebate approximately equal to 63 cents/KWh and 12 cents/KWh is average energy price from standard pricing schedule
    - Customer faces approximately same marginal price as CPP customer during CPP period is rebate is being paid (63 cents/KWh + 12 cents/KWh = 75 cent/KWh)

PowerCentsDC Pricing Options

- Hourly pricing plan
  - Hourly energy prices based day-ahead PJM prices
  - Hourly pricing curve made more extreme
    - High price periods upweighted slightly
- Treatment received by customers
  - All types of customers notified day before via automated phone call, email, or text page
  - CPP and CPR customers notified day before CPP event occurs
    - CPP event days during summer called when forecast of high temperature for day is above 90 degrees
    - CPP event days during winter called when forecast of low temperature for day is below 18 degrees
  - Hourly pricing customers receive notification of high price (HP) warning hour
    - Hours when day-ahead price for energy is above 23 cents/KWh (> $230/MWh) during summer months (between 1/3 to 1/4 of CPP price)
    - Hours when day-ahead price for energy is above 15 cents/KWH (> $150/MWh) during winter months

AMI Communication Networks



Dataset Used in Analysis

- Hourly consumption for 1,245 customers over period July 21, 2008 to March 17, 2009
  - Summer period is July 21 to October 31
  - Winter period is November 1 to March 17
- ln(Q(i,h)) = Natural logarithm of consumption for location i during hour of sample h in KWh
- Hour(h) = Indicator for hour-of-sample h, h=1,…,24xD where D is number of days in sample period
  - Controls for temperature and system conditions differences across hours of sample

Dataset Used in Analysis

- Treat(i,j) = Indicator for whether customer i is in treatment group j (j=CPP, CPR, and HP)
- CCP(h) = Indicator for whether hour of sample h is a critical peak hour
- HP(h) = Indicator for whether hour of sample h is a high price warning period
- THERM(i) = Indicator for whether customer i has a smart thermostat

Measuring Treatment Effect

- Average treatment effect for CPP event and HP event
  - $\ln(Q(i,h)) = \alpha(CPP\_PER(i,h)) + \beta(HP\_PER(i,h)) + \lambda_h + \delta_i + \varepsilon_{ih}$
  - δ_i = location-specific fixed effect (controls for persistent differences in consumption across locations)
  - λ_h = hour-of-sample fixed effects (controls for persistent differences in consumption across hours in sample)
  - ε_{ih} = unobservable mean zero stochastic disturbance
- CPP_PER(i,h) = CPP(h)*Treat(i,CPP or CPR)
- HP_PER(i,h) = HP(h)*Treat(i,HP)
- Other variables added to other models
  - CPP_PER(i,h)*THERM(i)
  - HP_PER(i,h)*THERM(i)
  - CPM_K(i,h) = CPP(h)*Treat(i,K) for customer type M = P or R
    - Different treatment effect for CPP versus CPR treatment by customer type

Results Full Sample, Group R

Parameter	Estimate	Std. Error	t Value
HP_PER	-0.03003	0.01110	-2.70
CPP_PER	-0.09087	0.00731	-12.43

Parameter	Estimate	Std. Error	t Value
HP_PER	-0.03010	0.01110	-2.71
CPP_R	-0.13030	0.00939	-13.88
CPR_R	-0.05315	0.00923	-5.76

Parameter	Estimate	Std. Error	t Value
HP_PER	-0.04788	0.01262	-3.80
CPP_R	-0.10636	0.01034	-10.29
CPR_R	-0.05021	0.01059	-4.74
HP_PER*THERM	-0.01799	0.01285	-1.40
CPP_R*THERM	-0.11060	0.02001	-5.53
CPR_R*THERM	-0.00996	0.01771	-0.56

1) HP, CPP, and CPR all show negative treatment effect
2) CPP treatment effect more than twice CPR
3) CPP treatment effect more than almost 3 times HP
4) Smart thermostat increases magnitude of all treatment effects

Results Summer Sample, Group R

Parameter	Estimate	Std. Error	t Value
HP_PER	-0.02574	0.01312	-1.96
CPP_PER	-0.08892	0.00810	-10.98

Parameter	Estimate	Std. Error	t Value
HP_PER	-0.02576	0.01312	-1.96
CPP_R	-0.12529	0.01031	-12.15
CPR_R	-0.05349	0.01021	-5.24

Parameter	Estimate	Std. Error	t Value
HP_PER	-0.05149	0.01488	-3.46
CPP_R	-0.09653	0.01131	-8.54
CPR_R	-0.04819	0.01169	-4.12
HP*THERM	-0.03819	0.02679	-1.42
CPP_R*THERM	-0.13592	0.02197	-6.19
CPR_R*THERM	-0.01801	0.01947	-0.93

HP, CPP, and CPR all show negative treatment effect
CPP treatment effect more than twice CPR and almost 3 times HP
Smart thermostat increases magnitude of all treatment effects

Results Full Sample, Group AE

Parameter	Estimate	Std. Error	t Value
HP_PER	-0.17501	0.02350	-7.45
CPP_PER	-0.16162	0.01433	-11.28

Parameter	Estimate	Std. Error	t Value
HP_PER	-0.17514	0.02350	-7.45
CPP_AE	-0.24578	0.01841	-13.35
CPR_AE	-0.08462	0.01781	-4.75

Parameter	Estimate	Std. Error	t Value
HP_PER	-0.16161	0.02657	-6.08
CPP_AE	-0.17026	0.02248	-7.57
CPR_AE	-0.07833	0.02071	-3.78
HP*THERM	-0.05260	0.04824	-1.09
CPP_AE*THERM	-0.19146	0.03269	-5.86
CPR_AE*THERM	-0.01949	0.03266	-0.60

HP, CPP, and CPR all show a negative treatment effect that is larger in absolute value than corresponding treatment effect for R customers
CPP treatment effect more than twice CPR
HP treatment effect is slightly smaller than CPP treatment effect
Smart thermostat increases magnitude of all treatment effects

Results Summer Sample, Group AE

Parameter	Estimate	Std. Error	t Value
HP_PER	-0.05787	0.02686	-2.15
CPP_PER	-0.12629	0.01439	-8.78

Parameter	Estimate	Std. Error	t Value
HP_PER	-0.05799	0.02686	-2.16
CPP_AE	-0.22356	0.01841	-12.14
CPR_AE	-0.03644	0.01788	-2.04

Parameter	Estimate	Std. Error	t Value
HP_PER	-0.05069	0.03054	-1.66
CPP_AE	-0.13325	0.02240	-5.95
CPR_AE	-0.01901	0.02073	-0.92
HP*THERM	-0.02749	0.05417	-0.51
CPP_AE*THERM	-0.23122	0.03265	-7.08
CPR_AE*THERM	-0.05452	0.03284	-1.66

HP, CPP, and CPR all show a negative treatment effect that is similar in absolute value to corresponding treatment effect for R customers
CPP treatment effect more than five time CPR treatment effect
HP treatment effect is ¼ of CPP treatment effect
Smart thermostat increases magnitude of all treatment effects

Results Group RAD-R

Full Sample

Parameter	Estimate	Std. Error	t Value
CPR_PER	-0.13609	0.01768	-7.70
CPR_PER*THERM	-0.04193	0.02039	-2.10

Summer Sample

Parameter	Estimate	Std. Error	t Value
CPP_PER	-0.10009	0.01840	-5.44
CPP_PER*THERM	-0.04727	0.04841	-0.98

Winter Sample

Parameter	Estimate	Std. Error	t Value
CPP_PER	-0.13171	0.03451	-3.82
CPP_PER*THERM	-0.05261	0.08962	-0.59

Larger CPR Treatment Effect than for either R or AE customers
Smart meter increases magnitude of treatment effect

Results Group RAD-AE

Full Sample

Parameter	Estimate	Std. Error	t Value
CPP_PER	-0.1204	0.06173	-1.96
CPP_PER*THERM	-0.0227	0.01595	-1.36

Summer Sample

Parameter	Estimate	Std. Error	t Value
CPP_PER	-0.14308	0.10514	-1.36
CPP_PER*THERM	-0.05561	0.05523	-1.01

Winter Sample

Parameter	Estimate	Std. Error	t Value
CPP_PER	-0.07944	0.04695	-1.69
CPP_PER*THERM	-0.07661	0.12336	-0.62

Larger CPR Treatment Effect than for either R or AE customers
Smart meter increases magnitude of treatment effect

Preliminary Answers to Research Questions

- Price responsiveness
  - Both R and AE customers reduce their consumption in response to CPP and HP hours
  - Effect (% reduction in consumption from CPP or HP event) larger for AE customers relative to R customers in both summer and winter
  - For R customers effect primarily confined to summer periods
- RAD customers (Low Income)
  - RAD-R and RAD-AE customers reduce their consumption in response to CPP event
    - Treatment effects are larger than CPR treatment effect for R and AE customers
- Difficult to see evidence of "cost-of-taking action" for hourly pricing
  - Hourly pricing effect is between 1/3 to ¼ of size of CPP effect consistent with HP warning being for energy prices that are 1/3 to ¼ the size of CPP energy price
  - For AE customers large full-sample and winter HP warning effect

Preliminary Answers to Research Questions

- Strong evidence in favor of option-to-quit effect
  - For both R and AE customers CPR effects is ½ to ¼ of CPP effect
  - For RAD customers not possible to examine this hypothesis because only CPR treatment was applied to RAD-R and RAD-AE
- Smart thermostat significantly enhances treatment effect
  - Almost doubles effect for CPP treatment for AE customers
  - Also increases treatment effects for for R customers
  - Increases treatment effect for RAD-R and RAD-AE customers, but results not very precisely estimated

Conclusions

- Default hourly-pricing may not be that difficult for consumers to respond to
  - High day-ahead wholesale price hours tend to cluster together, similar to CPP periods
  - Cost of taking action does not seem substantial
    - Further work required to provide more definitive conclusion
- Default CPR tariff inferior to default CPP tariff
  - Loss in price-responsiveness could be large
  - "Option-to-quit" produces substantially smaller treatment effect
  - Further argument for default pass-through of hourly price or CPP default
- Smart thermostats significantly enhance price responsiveness of all customers
  - Air-conditioning and electric heating intensive areas may benefit most
- Low-income consumers can achieve significant price responsiveness
  - Almost double treatment effect of RAD-AE customers on CPR relative to R and AE customers on CPR
  - Low income consumers can achieve significant economic benefits from dynamic pricing

Questions/Comments

For more information:

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