

DO CUSTOMERS RESPOND TO TIME-VARYING RATES: A PREVIEW OF ARCTURUS 3.0

Brattle Working Paper

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Evolution of Brattle's survey of pricing experiments

Drs. Sanem Sergici and Ahmad Faruqui undertook their initial survey of pricing experiments in 2010 and published their results in:

- “Household response to dynamic pricing of electricity—a survey of 15 experiments,” *Journal of Regulatory Economics* (2010), 38:193-225.

We expanded this survey in 2013 and published a meta-analysis of this data:

- “Arcturus: International Evidence on Dynamic Pricing,” *The Electricity Journal*, 26:7, August/September 2013, pp. 55-65

In 2017, we updated that meta-analysis to include a total of 337 observations:

- “Arcturus 2.0: A meta-analysis of time-varying rates for electricity,” with Sanem Sergici and Cody Warner, *The Electricity Journal*, 30:10, December 2017, pp. 64-72.

As of the end of 2022, 60 more observations have become available for a total of 397 observations, and we have updated the meta-analysis with these additional data points

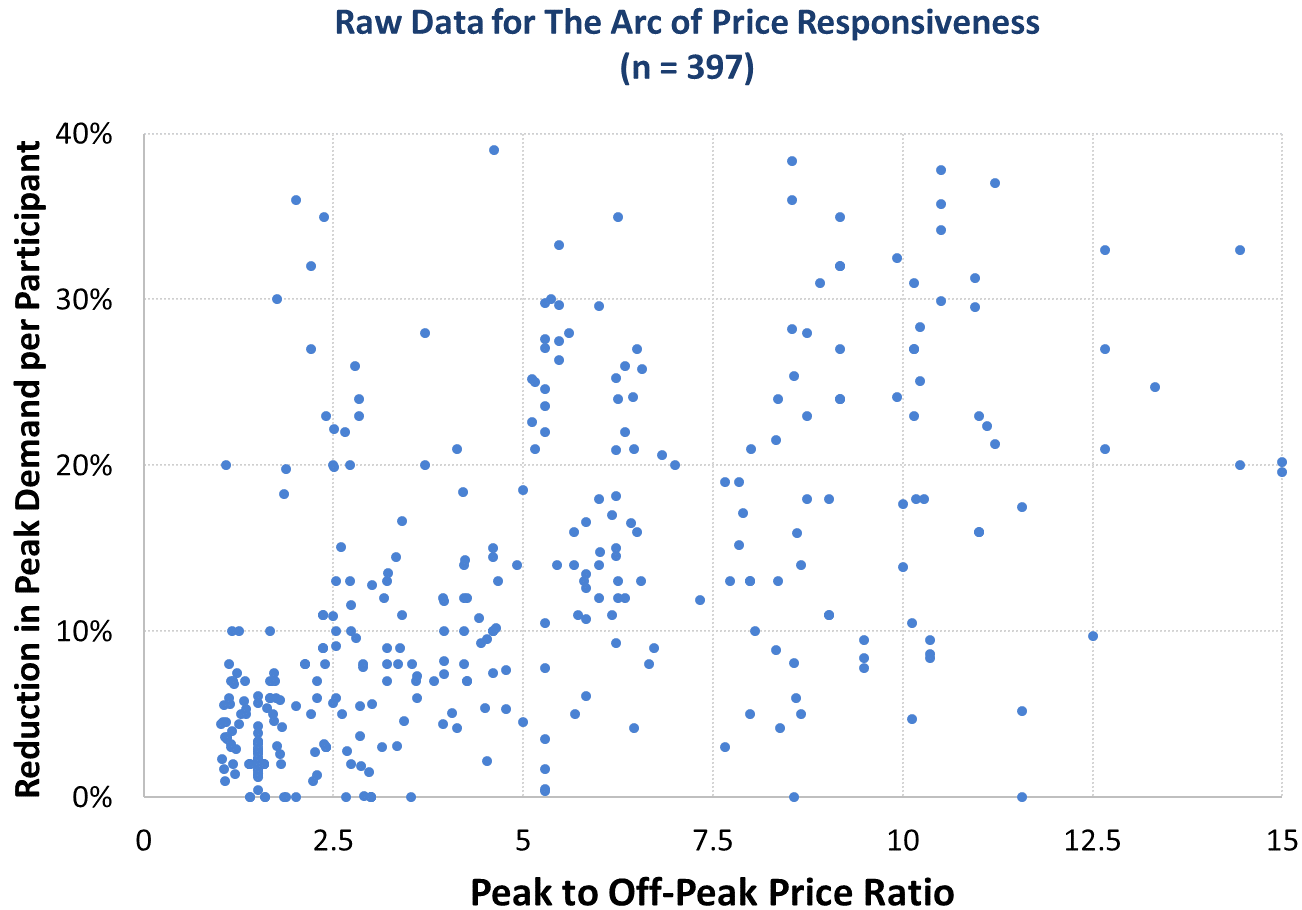
- We are on the verge of publishing Arcturus 3.0 and this slide deck presents our initial results

What's new and different in Arcturus 3.0?

The new analysis allows us to not only update the previous relationships between time-varying rates (TVR) and response but address some new questions:

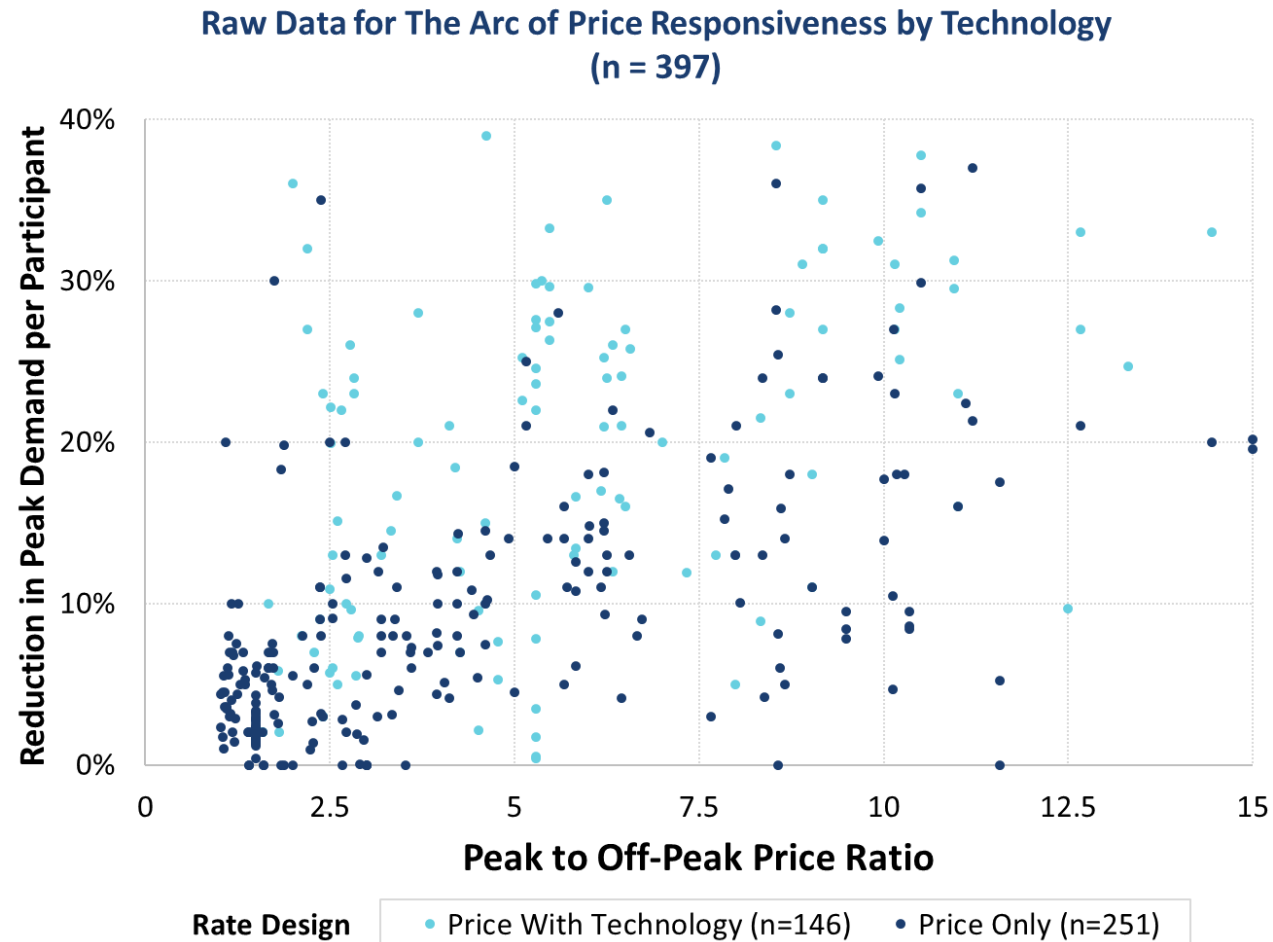
- Does the arc of price response differ across utilities which are summer versus winter peaking?
- Does it differ across seasons for summer peaking utilities?
- Does the arc differ for CPP rates versus PTR rates?
- Does the arc differ based on whether enrollment is opt-in or opt-out?

Data from 397 deployments of TVRs resembles stars in the night sky – we have called it Arcturus; no pattern is apparent



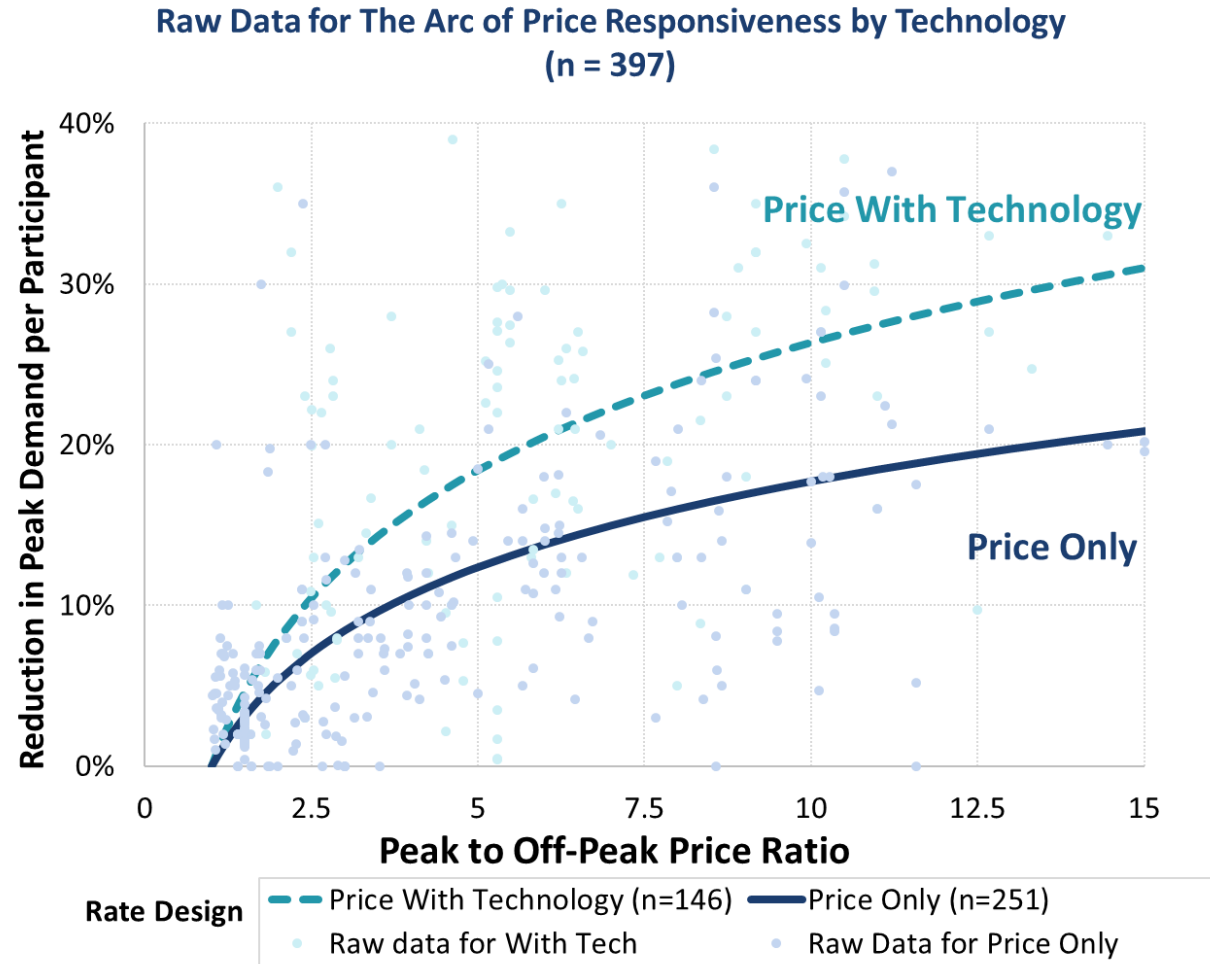
Notes: Treatments that have no impact and are non-significant are excluded from the graph. RTP treatments are also excluded.

In this chart, we code the data into (a) price only (n = 251) and (b) price with technology (n = 146); no clear pattern emerges



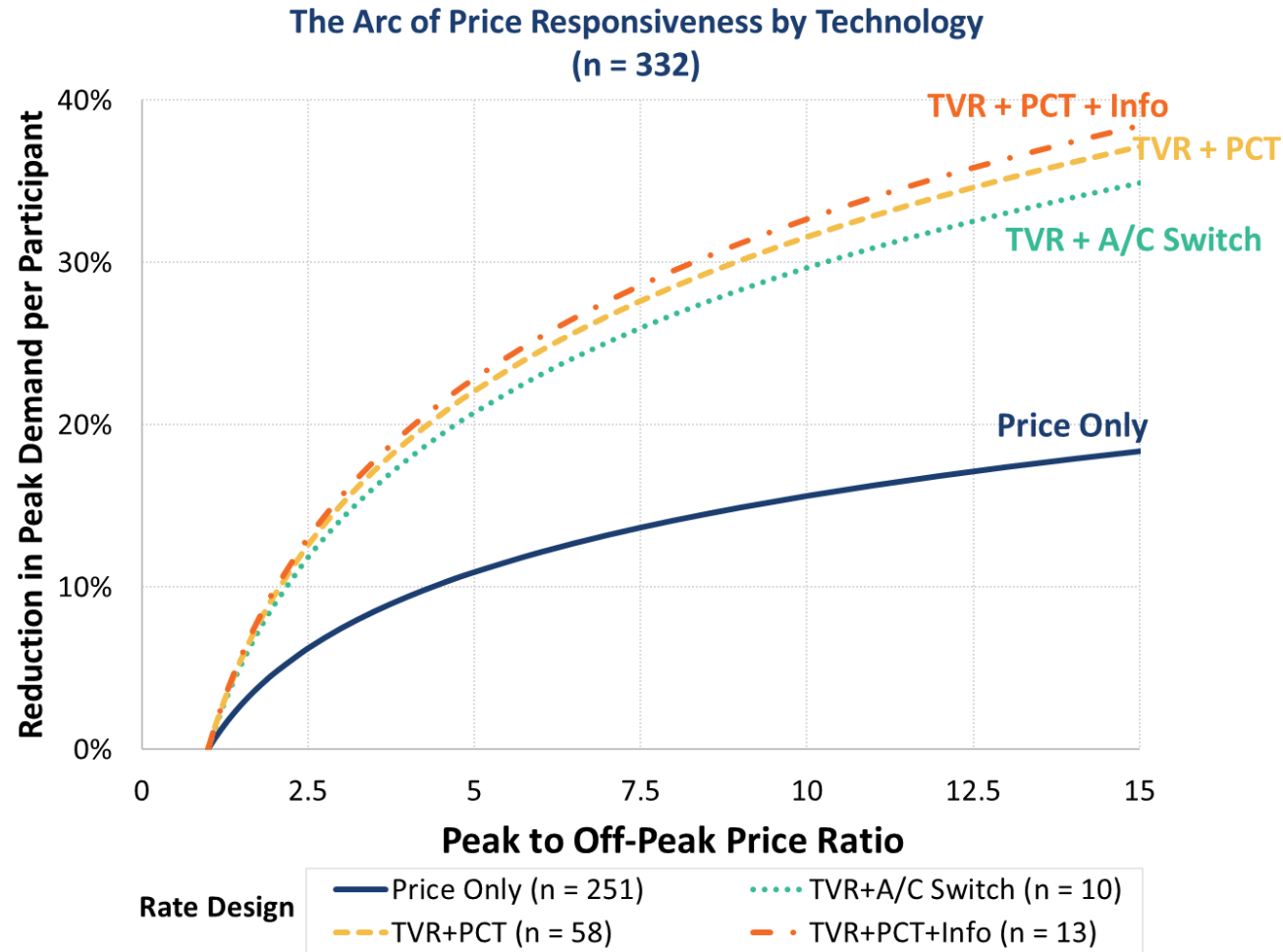
Notes: Treatments that have no impact and are non-significant are excluded from the graph. RTP treatments are also excluded.

Two “arcs of price response” emerge when we fit regression lines for TVRs with and without technology enablement – the difference is statistically significant



Notes: Treatments that have no impact and are non-significant are excluded from the graph. RTP treatments are also excluded.

Pairing TVR with programmable communicating thermostats (PCT) and information treatments more than doubles the TVR impacts for a given P/OP ratio



Notes: A/C Switch includes Energy Orb, A/C switch, and any load control devices. PCT refers to programmable communicating thermostat or smart thermostat. PCT + Info includes all programmable communicating thermostat with in-home display (IHD).

We observe four types of additional treatments paired with TVRs:

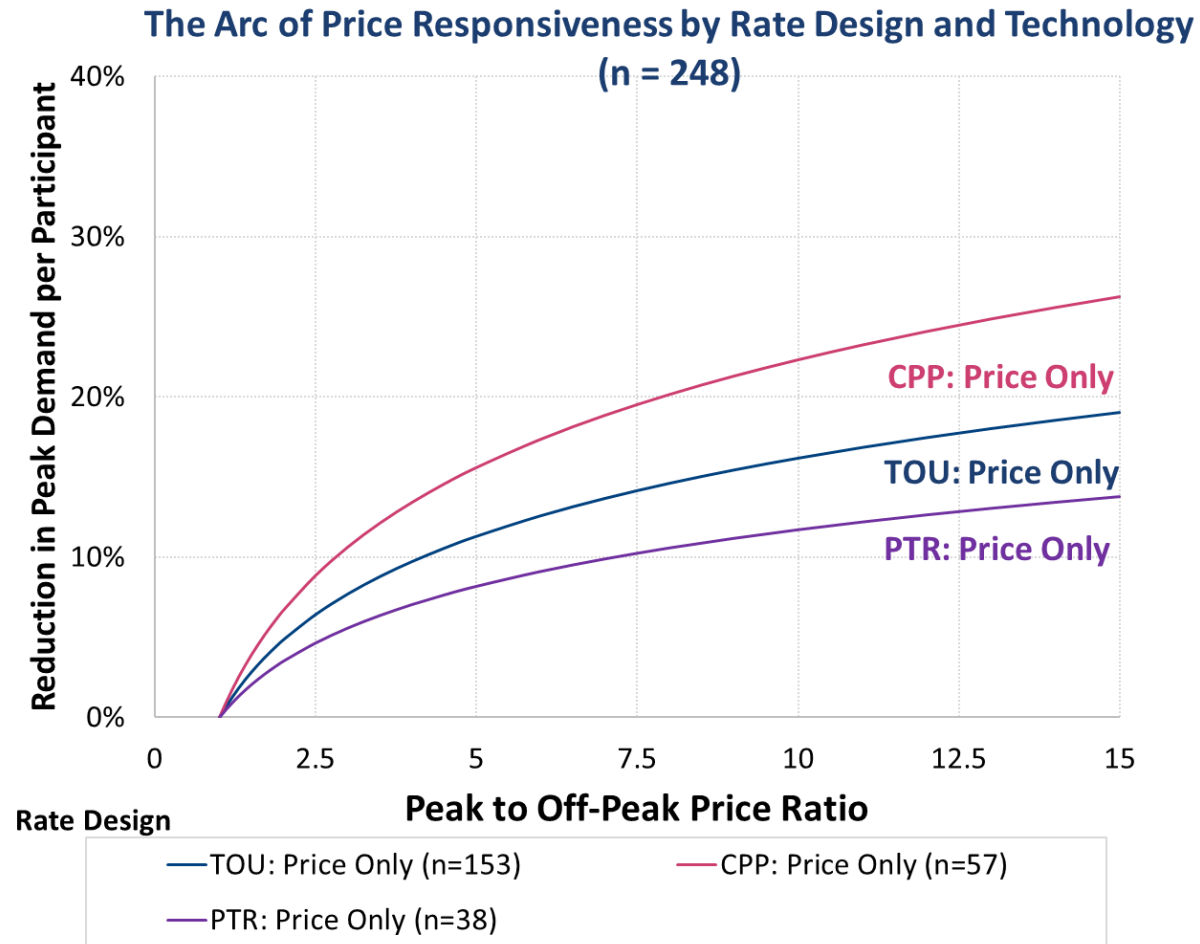
- Programmable communicating thermostats (PCT)
- Direct load control or A/C switches
- Information feedback
- PCT and information feedback

TVR+PCT, TVR+PCT+Info, and TVR+A/C Switch program impacts are significantly different from those of the price only programs

TVR+Info is not statistically different from price only

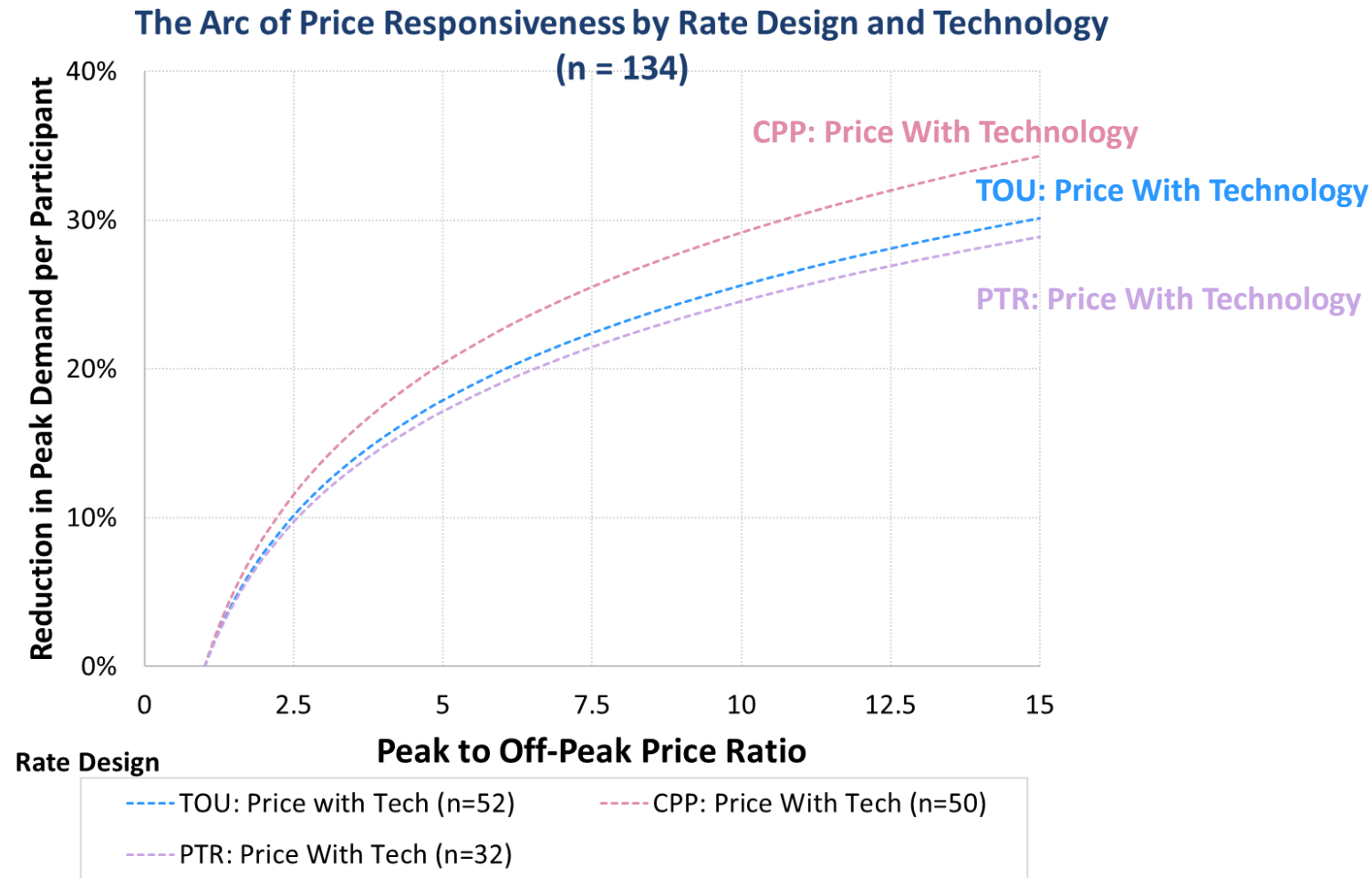
TVR+PCT, TVR+PCT+Info, TVR+A/C Switch are not statistically significant from each other

The difference in the arcs for TOU, CPP and PTR (without technology) is statistically significant



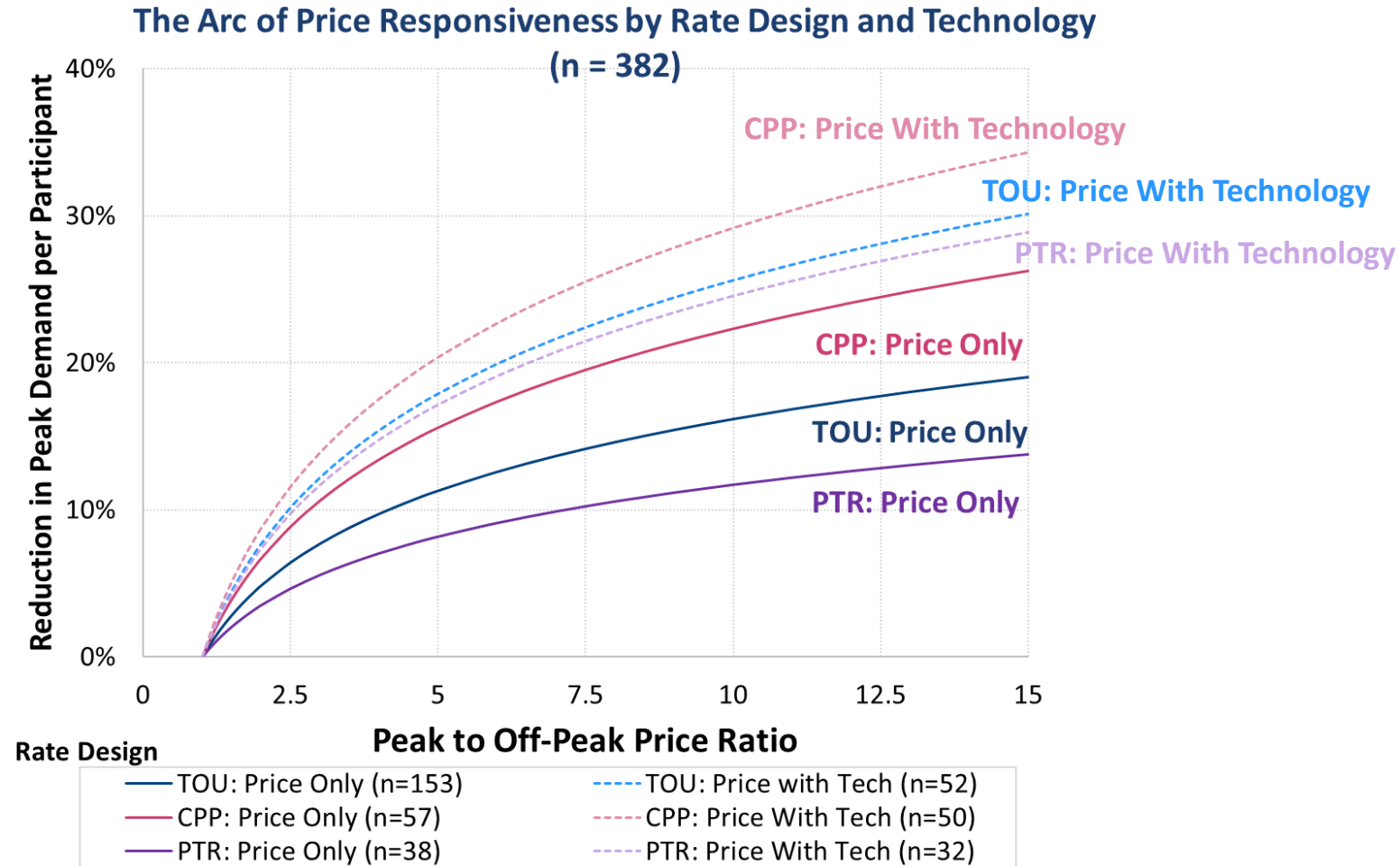
Notes: VPP treatments are excluded.

TOU and PTR arcs, when paired with technology, are not statistically different from each other



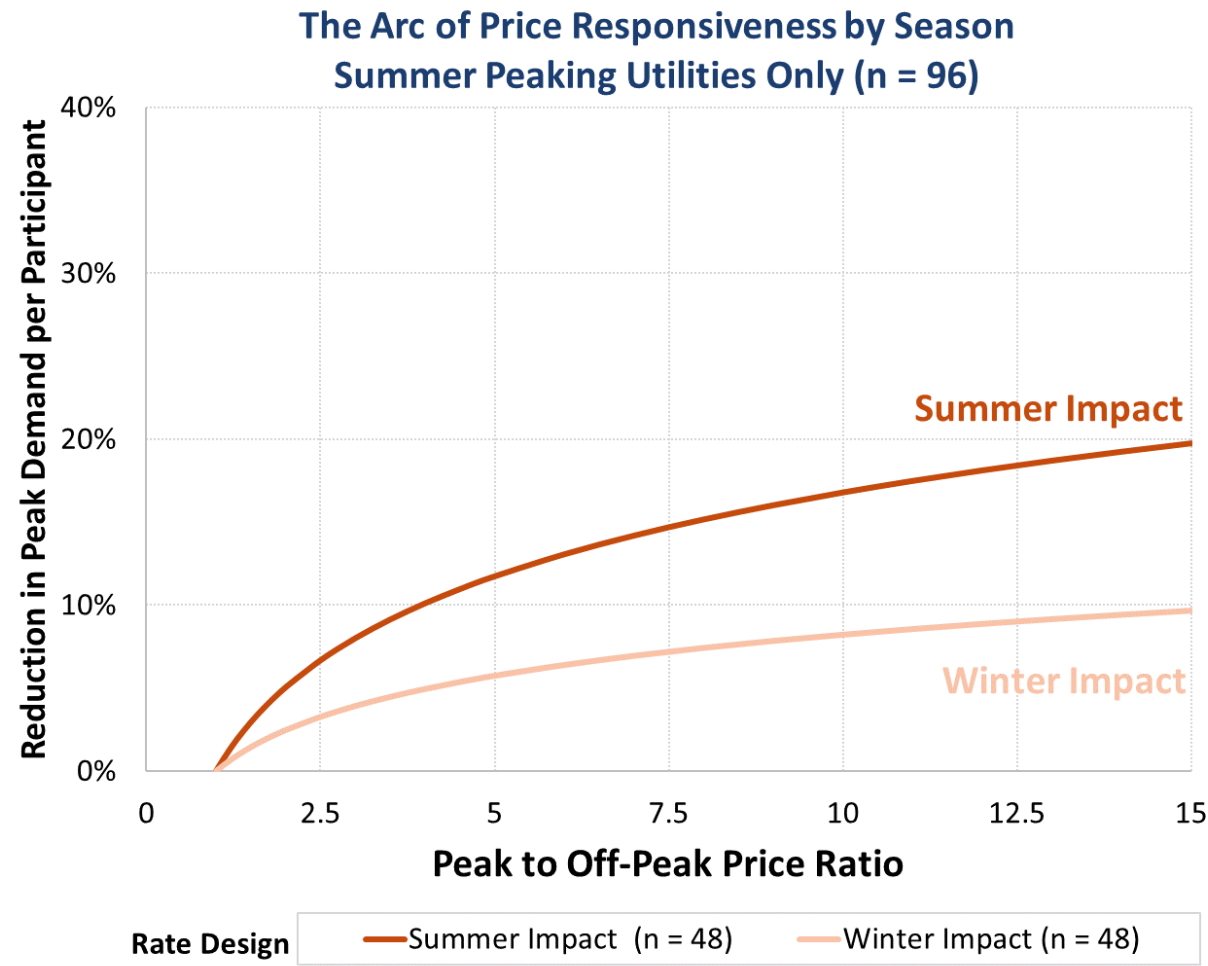
Notes: VPP treatments are excluded.

The six arcs for TOU, CPP and PTR, with and without tech, are shown below



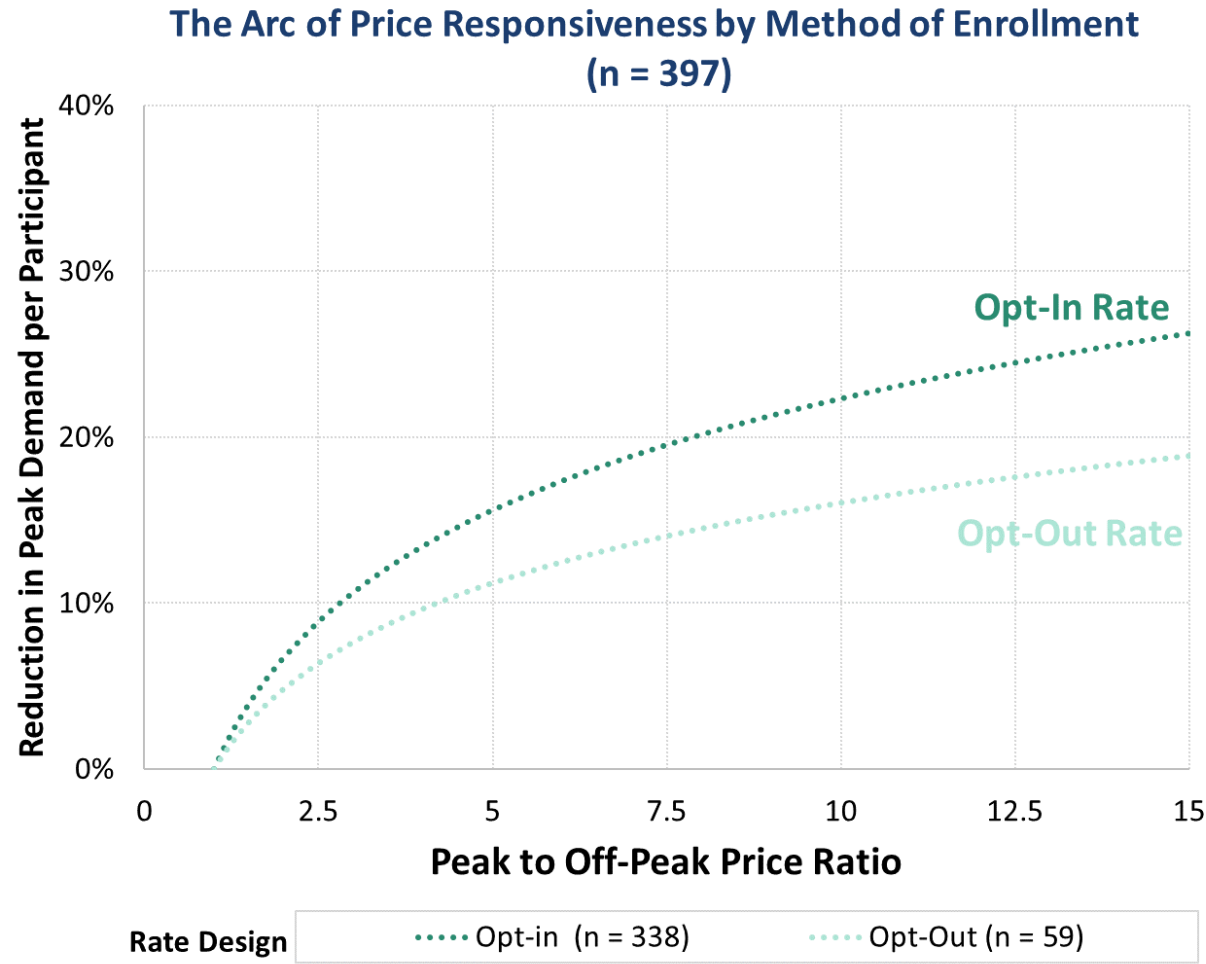
Notes: VPP treatments are excluded.

For *summer peaking utilities*, the impact of TVR is higher in the summer season than in the winter season; the difference is statistically significant



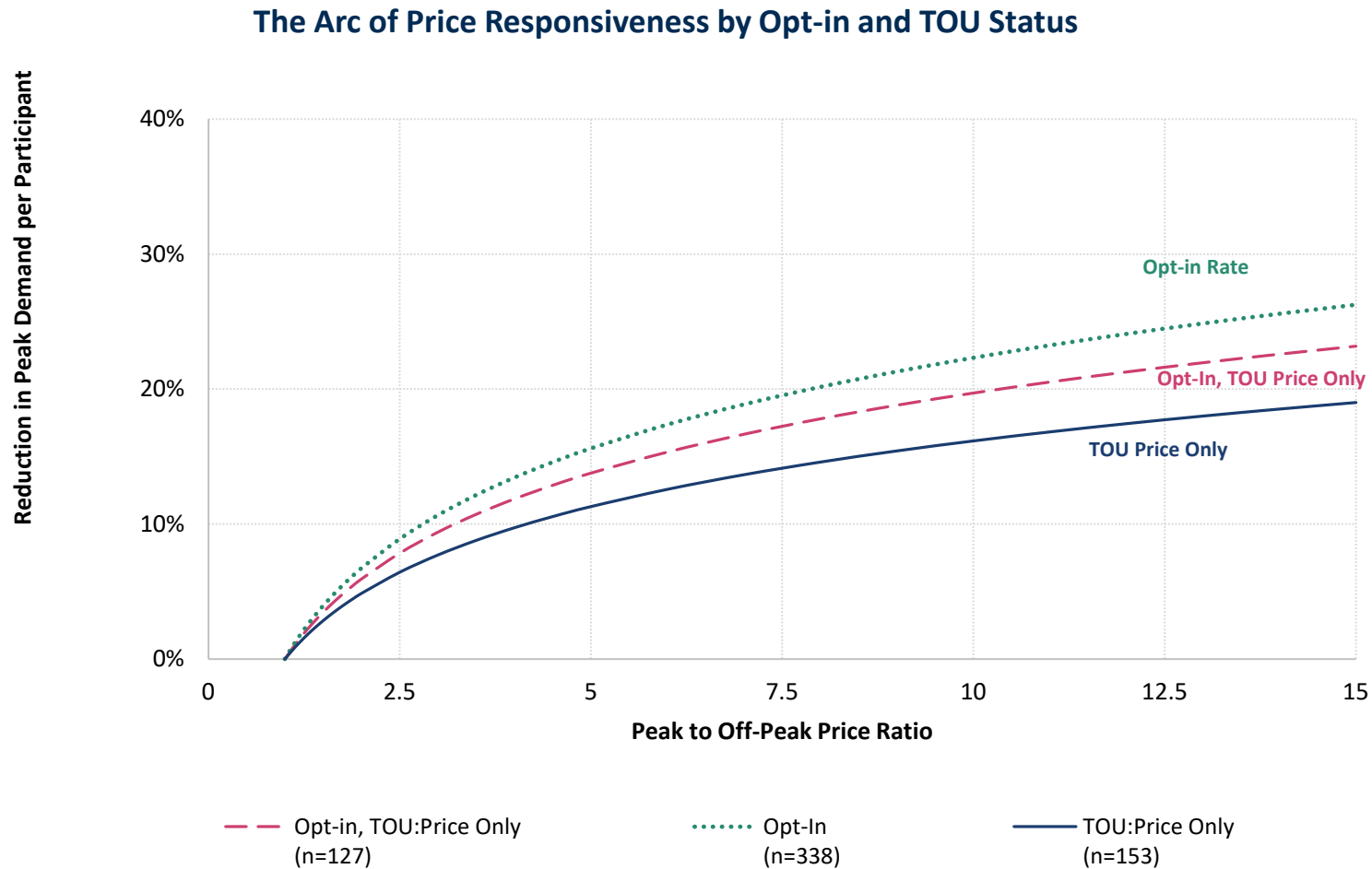
Notes: Among all treatments that are summer peaking, there are 48 pairs of annual results (summer and winter). This model does not differentiate between treatments that are price only or paired with technology.

The impact of TVRs deployed in opt-in mode exceeds that in opt-out mode; the difference is statistically significant

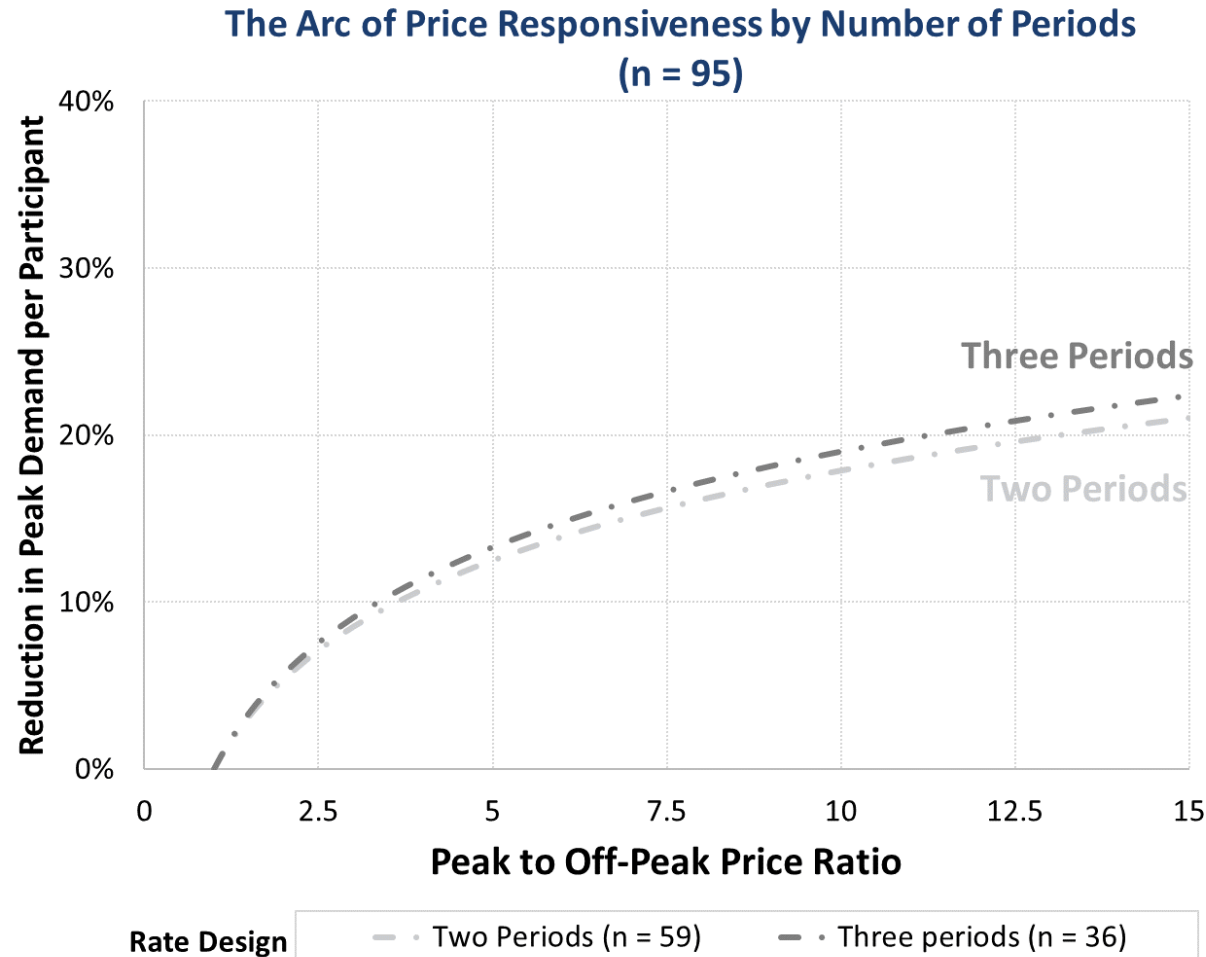


Notes: This model does not differentiate between treatments that are price only or paired with technology.

The impact of TOU rates, when deployed in opt-in mode, is 20% more than the average TOU only impact from Arcturus



The impact of TVRs deployed with three periods exceeds that in two periods; the difference is not statistically significant



Notes: Among the database, only 95 treatments have the information for number of periods. This model does not differentiate between treatments that are price only or paired with technology.

The Arcturus Database has 410 observations from 80 pilots on four continents

Summary of Characteristics of Dynamic Pricing Experiences

Rate Design	N	Season			Recruitment		Technology			
		Summer Only Rate	Winter Only Rate	Annual Rate	Opt-In	Opt-Out	With PCT	A/C Switch	Info	No Tech
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
TOU	205	21%	36%	23%	80%	20%	13%	0%	12%	75%
CPP	107	3%	66%	n.a.	90%	10%	21%	2%	24%	53%
PTR	70	3%	83%	n.a.	91%	9%	20%	11%	14%	54%
VPP	15	7%	80%	n.a.	100%	0%	53%	0%	27%	20%
All	397	12%	54%	13%	85%	15%	18%	3%	16%	63%

Notes: 13 RTP treatments are not included in the summary table.

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Utility, Municipality, or Pilot	Year(s) of Study	Type(s) of Rate	Country	U.S. State or Country	US State or CA Province	Number of Treatments
[1] Automated Demand Response Sytem Pilot	2004 - 2005	TOU, CPP	United States	CA	CA	4
[2] Ameren Illinois	2008, 2010	RTP	United States	IL	IL	6
[3] Ameren Missouri	2004 - 2005	CPP	United States	MO	MO	4
[4] Anaheim Public Utilities	2005	PTR	United States	CA	CA	1
[5] Ausgrid	2006 - 2008	TOU, CPP	Australia	Australia	-	5
[6] Austin Energy	2013 - 2014	CPP	United States	TX	TX	1
[7] Baltimore Gas & Electric Company	2008 - 2011, 2018 - 2020	CPP, PTR, TOU	United States	MD	MD	23
[8] BC Hydro	2008	TOU, CPP	Canada	British Columbia	British Columbia	8
[9] British Gas; Northern Powergrid	2012 - 2013	TOU	United Kingdom	United Kingdom	-	1
[10] California Statewide Pricing Pilot	2004 - 2005	TOU, CPP	United States	CA	CA	4
[11] City of Fort Collins	2015, 2019	TOU	United States	CO	CO	2
[12] City of Kitakyushu	2012 - 2013	CPP, VPP	Japan	Japan	-	8
[13] City of Kyoto	2012 - 2014	CPP	Japan	Japan	-	4
[14] Commonwealth Edison Company	2011, 2015, 2019	TOU, CPP, PTR	United States	IL	IL	9
[15] Community Energy Cooperative	2005	RTP	United States	IL	IL	1
[16] Connecticut Light & Power Company	2009	TOU, CPP, PTR	United States	CT	CT	18
[17] Consolidated Edison	2019	TOU	United States	NY	NY	4
[18] Consumers Energy	2010	CPP, PTR	United States	MI	MI	3
[19] Country Energy	2005	CPP	Australia	Australia	-	1
[20] Delmarva Power & Light (DPL)	2018 - 2020	TOU	United States	MD	MD	4
[21] Department of Public Utilities in Los Alamos County	2013	CPP, PTR	United States	NM	NM	3
[22] Detroit Edison Company	2013	CPP	United States	MI	MI	4
[23] EDF Energy; E.ON; Scottish Power; Southern Energy	2007 - 2010	TOU	United Kingdom	United Kingdom	-	1
[24] Eco+ Thermostat Optimization	2019	TOU	Canada	Ontario	Ontario, CA, FL	5
[25] Energex; Ergon	2011 - 2013	CPP	Australia	Australia	-	2
[26] Evergy Missouri	2020	TOU	United States	MO	MO	4
[27] FirstEnergy Corporation	2012 - 2014	PTR	United States	OH	OH	12
[28] Florida Power & Light Company	2011	CPP	United States	FL	FL	1
[29] GPU, Inc.	1997	TOU	United States	NJ	NJ	2
[30] Green Mountain Power	2012 - 2013	CPP, PTR	United States	VT	VT	8

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Utility, Municipality, or Pilot	Year(s) of Study	Type(s) of Rate	Country	U.S. State or Country	US State or CA Province	Number of Treatments
[31] Gulf Power Company	2000 - 2002	TOU, CPP	United States	FL	FL	2
[32] Heartland PTR	2016	PTR	United States	KS	KS	1
[33] Hydro One Limited	2007	TOU	Canada	Ontario	Ontario	2
[34] Hydro Ottawa	2007	TOU, CPP, PTR	Canada	Ontario	Ontario	9
[35] Hydro-Québec	2008 - 2010	CPP, PTR	Canada	Quebec	Quebec	4
[36] Idaho Power Company	2006	TOU, CPP	United States	ID	ID	2
[37] Integral Enegy	2007 - 2008	CPP	Australia	Australia	-	2
[38] Ireland	2010	TOU	Ireland	Ireland	-	16
[39] Italy	2010 - 2012	TOU	Italy	Italy	-	1
[40] Kansas City Power and Light Company	2012 - 2014	TOU	United States	KS/MO	KS/MO	2
[41] Marblehead Municipal Electric Light Department	2011 - 2012	CPP	United States	MA	MA	2
[42] Mercury NZ	2008	TOU	New Zealand	New Zealand	-	3
[43] Newmarket - Tay Power Distribution Limited	2009	TOU	Canada	Ontario	Ontario	1
[44] Newmarket Hydro	2007	TOU, CPP	Canada	Ontario	Ontario	2
[45] Northern Ireland	2003 - 2004	TOU	United Kingdom	United Kingdom	-	1
[46] NV Energy	2013 - 2015	TOU, CPP	United States	NV	NV	16
[47] Oklahoma Gas & Electric Energy Corporation	2011	TOU, VPP	United States	OK	OK	12
[48] Olympic Peninsula Project	2007	CPP, RTP	United States	WA/OR	WA/OR	2
[49] Ontario Power Authority	2012 - 2014	TOU	Canada	Ontario	Ontario	24
[50] Pacific Gas & Electric Company	2009 - 2016; 2019	TOU, CPP	United States	CA	CA	34
[51] PacifiCorp	2002 - 2005	TOU	United States	OR	OR	4
[52] PECO	2014	TOU	United States	PA	PA	1
[53] Portland General Electric	2002 - 2003; 2011 - 2013; 2017	TOU, CPP, PTR	United States	WA	WA	6
[54] Potomac Electric Power Company (PEPCO)	2010, 2018 - 2020	CPP, RTP, PTR, TOU	United States	DC/MD	DC/MD	11
[55] PSE&G	2006 - 2007	TOU, CPP	United States	NJ	NJ	8
[56] Puget Sound Energy	2001	TOU	United States	WA	WA	1
[57] Sacramento Municipal Utility District	2011 - 2013	TOU, CPP	United States	CA	CA	20
[58] Salt River Project	2008 - 2009	TOU	United States	AZ	AZ	2
[59] San Diego Gas & Electric Company	2011, 2015 - 2016	TOU, CPP, PTR	United States	CA	CA	13
[60] SmartGrid SmartCity Pilot	2012 - 2014	CPP	Australia	Australia	-	4

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Utility, Municipality, or Pilot	Year(s) of Study	Type(s) of Rate	Country	U.S. State or Country	US State or CA Province	Number of Treatments
[61] Southern California Edison Company	2016	TOU	United States	CA	CA	6
[62] Southwestern Ontario	2011 - 2012	TOU	Canada	Ontario	Ontario	1
[63] Sun Valley Electric Supply Company	2011	CPP	United States	ND	ND	4
[64] UK Power Networks	2013	CPP	United Kingdom	United Kingdom	-	1
[65] Vermont Electric Cooperative	2013 - 2014	VPP	United States	VT	VT	3
[66] Xcel Energy, Inc.	2011 - 2013; 2019	TOU, CPP, PTR	United States	CO	CO	24

Notes:

The results of one time-varying pilot are not public, so it is excluded here.

Some utilities have conducted multiple pilots that experiment with different types of time-varying rates.

These pilots include:

City of Kitakyushu (Kato et. al study; Ito et. al study)

Commonwealth Edison Company (2011 TOU, CPP, PTR study; 2015 PTR study)

Pacific Gas & Electric (2009-2016 TOU and CPP SmartRate; 2019 E-TOU)

Portland General Electric (2002 TOU Pilot; 2011 CPP Pilot; 2017 Flexible Pricing Pilot)

San Diego Gas & Electric (Residential Peak Time Rebate and Small Customer Technology Deployment Program, Voluntary Residential CPP and TOU Rates)

SMUD (Residential Summer Solutions; Smart Pricing Options Pilot)

Xcel Energy (2011 - 2013 SmartGridCity Pricing Pilot Program; 2019 RE-TOU Trial)

The Joint Utilities in Maryland (BGE, DPL, PEPCO) have conducted PC44 Time of Use Pilots (2019,2020) together.

Including the pilots noted above brings the total count to 80 pilots.