Demand Response: smart market designs for smart consumers

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An illuminating example of baseline inflation

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  - PTR enables customers to resell power at the spot price
  - if information about baseline is asymmetric, baseline inflation ensue (Wolak, 2007)

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    - otherwise, partial enrollment occurs

Previous debates about PTR and literature review

- *A false start*: regulators have (surprisingly) forgotten that electricity, like any other good, must be bought before it can be sold (Chao, 2010; Hogan, 2010; Crampes and Léautier, 2012).

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- *Achieved reductions in peak demand*: PTR may be less efficient than CPP in reducing peak demand (Newsham and Bowker, 2010; Faruqui and Sergici, 2010). Due to cognitive biases and bill protection? (Fenrick et al., 2014)

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- $q^*(\theta, t)$ the socially optimal consumption: $q^*(\theta, t) = q(p(t), \theta, t)$

Optimal "stand alone" contract

Mechanism:

1. Retailer proposes a menu $\{T(.), t \to \bar{q}(., t)\}_\theta$ of payments $T(.)$ and maximum consumption $\bar{q}(., t)$
2. Consumers report $\hat{\theta}$, hence pay $T(\hat{\theta})$ and get allocated a maximum consumption $\bar{q}(\hat{\theta}, t)$
3. State t is realized. Customers consume any quantity $q \leq \bar{q}(\hat{\theta}, t)$ and resell the rest at $p(t)$

Proposition

An IC socially optimal mechanism in which the lowest type gets the surplus she would get under RTP is such that:

1. *For almost all* (θ, t), $\bar{q}(\theta, t) \geq q^*(\theta, t)$
2. $T(\theta) = \mathbb{E}_t \left[p(t)\bar{q}(\theta, t)\right]$

IC contract with a fixed price, full requirements contract

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Constrained mechanism (with mandatory opt-in):

1. Retailer proposes a menu $\{T(.), t \to \bar{q}(., t)\}_\theta$ of payments $T(.)$ and baseline consumption $\bar{q}(., t)$
2. Consumers report $\hat{\theta}$, hence pay $T(\hat{\theta})$ and get allocated a baseline $\bar{q}(\hat{\theta}, t)$
3. State t is realized. Customers can consume any quantity q, and resell $(\bar{q}(\hat{\theta}, t) - q)^+$ at $p(t)$. They pay $A + p^R q$ if they do not resell, and $A + p^R \bar{q}(\hat{\theta}, t)$ if they do.

Incentive compatible contract when a fixed price is offered

Define the indifference quantity $\hat{q}(\theta, t)$ such that

$$U(q(p^R, \theta, t), \theta, t) - p^R q(p^R, \theta, t) \equiv \begin{array}{l} U(q^*(\theta, t), \theta, t) - p^R \hat{q}(\theta, t) \\ +p(t)(\hat{q}(\theta, t) - q^*(\theta, t))^+ \end{array}$$

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An IC (constrained) optimal mechanism is such that:

1. *For almost all* (θ, t), $\bar{q}(\theta, t) \geq \hat{q}(\theta, t)$ *when* $p(t) > p^R$
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1. Some off-peak under-consumption occurs (not optimal)
2. No *ex ante* screening (consumers are indifferent between any high enough baseline)
3. Current PTR implementations set $T(\theta) = 0$. Hence, they naturally lead to arbitrage, i.e., baseline inflation

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- This leads to an apparent policy dilemma: if information asymmetry is an issue, ignoring it leads to costly and unjust baseline inflation, and including it leads to no enrollment in PTR
- However, since IC PTR/vCPP contracts increase social surplus, one should be able to induce at least some enrollment by modifying retail contracts, for example offering switching consumers a lower fixed fee ($B < A$) or off-peak price ($\underline{p} < p^R$)

Perfect competition among retailers and no subsidy

Proposition

Under perfect competition, variable CPP contracts converge toward RTP.

Proof.

Net surplus is higher closer to RTP. If a retailer offers a variable CPP contract away from RTP, a competitor can undercut her. □

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If customers staying on standard rate not subsidized, almost all consumers switch to RTP in equilibrium.

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- Using $V^{RTP}(\theta) = W^{RTP}(\theta)$, the no cross-subsidies condition can be rewritten:

$$\mathbb{E}_\theta\left[\left\{\underbrace{W^0(\theta) - W^{RTP}(\theta)}_{\leq 0} + \underbrace{V^{RTP}(\theta) - V^0(\theta)}_{\leq 0}\right\}\mathbf{1}_{V^0(\theta)\geq V^{RTP}(\theta)}\right] \geq 0$$

Perfect competition among retailers, maintained subsidies to non-switchers

The no cross-subsidies assumption may be demanding:

1. "*the fear of large redistributions across customers is possibly the largest impediment to further adoption of dynamic pricing*" (Joskow and Wolfram, 2012).
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If the standard rate remains constant, full enrollment is no longer guaranteed.

Benevolent monopoly retailer, no subsidies

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$$\mathbb{E}_{\theta t}\left[A + (p^R - p(t))q(p^R, \theta, t) | \Delta(\theta) \leq 0\right] \geq 0,$$

while the no-subsidy condition for switchers is

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  - Since this covariance term plays no role in the self-selection of consumers, a disproportionate amount of "costly-to-supply" consumers may enroll first, maintaining the IC PTR tariff at a high level and preventing further adoption

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- If a single crossing condition holds, solving the program yields a on-peak resale price lower than the spot price: efficiency loss on-peak compensated by the gains from increased enrollment.
- Under the exogenous constraint of a frozen historical tariff, perfect competition does not achieve the second-best.

Concluding observations

- Peak Time Rebate, while popular with policy makers, seems to be a difficult path to demand response: even if customers are required to purchase power before reselling it, information asymmetry may enable (some) customers to inflate their baseload, which would generate undue rents, but also could weaken system reliability

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- Accepting information asymmetry requires offering different retail contracts to customers enrolling in Peak Time Rebate, and modifying rates of non-switching customers. Full enrollment occurs only if retail competition is perfect and subsidies to non-switchers are not allowed
- Further research should therefore examine the empirical magnitude of this information asymmetry