Is mandating smart meters smart?

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Main messages

**Context:** policy makers worldwide mandate installation of smart grids, announcing significant demand management benefits

- **Main finding:** marginal net surplus is steeply decreasing as customer size decreases, and is worth only around 10\(\text{€}/\text{customer/year}\) for customer size less than 36 kV (compared to cost of meter installation around 25\(\text{€}/\text{customer/year}\)).

- **Policy implications:**
  1. Should we not refine cost-benefit analysis before spending billions?
  2. What is the business case for a "smart electricity" supplier?
  3. If total benefits from smart meters exceed the total costs, how do we allocate these?
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Joskow and Tirole (2007) model: optimal investment, spot and retail prices, and rationing, when a fraction of customers $\alpha$ faces wholesale spot price, and $(1 - \alpha)$ faces a constant retail price.

Equivalent to perfectly competitive long-term outcome.

Uncertain demand. Infinite number of possible states of the world, indexed by $t \geq 0$.

A single demand profile for all customers.

$N$ generation technologies, with marginal cost $c_n$ (increasing in $n$) and investment cost $r_n$ (decreasing in $n$).
Rationing price reactive customers never optimal

Constant price customers are rationed if and only if their Value of Lost Load (VoLL) is equal to (or lower than) $p(t)$, the wholesale spot price in state $t$

The optimal retail price is the weighted average wholesale price, where the weights are the marginal "rationed demand"

Total installed capacity determined by $(r_N, c_N)$ and demand. Installed capacity for technology $n < N$, determined by $(r_n, c_n)$ and $(r_{n+1}, c_{n+1})$

Expected price independant of $\alpha$:

$$\mathbb{E}[p(t)] = c_1 + r_1$$
Increasing the share of price reactive customers increases net surplus

- A marginal increase in $\alpha$ transforms customers facing a constant price into customers facing the marginal cost of production in every state of the world.
A specific case

- Linear inverse demand: $P(q, t) = a_0 - a_1 e^{-\lambda_2 t} - bq$
- Exponential distribution of the states of the world: $f(t) = \lambda_1 e^{-\lambda_1 t}$
- $\left(a_0, a_1, \lambda = \frac{\lambda_1}{\lambda_2}, b\right)$ calibrated using the average elasticity of demand $\eta$ for a given price $\delta$, and the 2009 French load duration curve
- Provides (almost) closed form expressions for optimal investment, prices, and marginal surplus $W'(\alpha)$
- Base case $\eta = -0.05$ at price $\delta = 100 \, \text{€/MWh}$, from Lijesen (2007). Upper estimate from Patrick and Wolak (1997) using UK data, and much higher than Lijesen (2007) own estimate on Dutch data, consistent with estimates from California experiment (Faruqui (2006)). Robustness check with $\eta = -0.1$. 

Léautier (Toulouse School of Economics)
Actual vs. fitted demand

Actual vs. fitted 2009 demand in France

Load (MW)

Time-periods

Actual demand
Fitted demand
Two technologies: nuclear plants ($n = 1$) and gas turbines ($n = 2$)

Cost provided by IAE (2010)

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$c_n$</td>
<td>10.99</td>
<td>71.56</td>
</tr>
<tr>
<td>$r_n$</td>
<td>34.16</td>
<td>6.00</td>
</tr>
</tbody>
</table>
Customers broken down in 4 classes, following the Commission de Régulation de l’Energie (CRE)
Marginal share increase per customer decreases rapidly

- Assume customer size (in MWh) constant within each class

<table>
<thead>
<tr>
<th>( \alpha (%) )</th>
<th>(0, 43)</th>
<th>(43, 58)</th>
<th>(58, 68)</th>
<th>(68, 100)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \delta \alpha (%/user) )</td>
<td>(1.24 \times 10^{-5})</td>
<td>(4.31 \times 10^{-7})</td>
<td>(2.21 \times 10^{-8})</td>
<td>(1.07 \times 10^{-7})</td>
</tr>
</tbody>
</table>

- Marginal surplus per customer is \( \delta W(\alpha) = W'(\alpha) \delta \alpha \). Discontinuous at the boundaries between classes. Define \( \delta W^- (\alpha) = W'(\alpha) \delta \alpha \) for \( \delta \alpha < 0 \) and \( \delta W^+ (\alpha) = W'(\alpha) \delta \alpha \) for \( \delta \alpha > 0 \).
Marginal benefits from switching for base elasticity estimate...

<table>
<thead>
<tr>
<th>$\alpha$ (%)</th>
<th>15</th>
<th>43</th>
<th>58</th>
<th>68</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>$K_1/Q^\infty$ (%)</td>
<td>59.3</td>
<td>59.3</td>
<td>59.3</td>
<td>59.3</td>
<td>59.4</td>
</tr>
<tr>
<td>$K_2/Q^\infty$ (%)</td>
<td>95.7</td>
<td>92.7</td>
<td>91.6</td>
<td>90.9</td>
<td>89.1</td>
</tr>
<tr>
<td>$W'(\alpha)$ (€ millions/year)</td>
<td>688</td>
<td>436</td>
<td>389</td>
<td>366</td>
<td>324</td>
</tr>
<tr>
<td>$\delta W^-$ (€ /user/year)</td>
<td>8512</td>
<td>5386</td>
<td>168</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>$\delta W^+$ (€ /user/year)</td>
<td>8512</td>
<td>188</td>
<td>9</td>
<td>4</td>
<td>n/a</td>
</tr>
</tbody>
</table>
... and for high elasticity estimate

<table>
<thead>
<tr>
<th>$\alpha$ (%)</th>
<th>16</th>
<th>43</th>
<th>58</th>
<th>68</th>
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</tr>
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<tbody>
<tr>
<td>$K_1/Q^\infty$ (%)</td>
<td>61.1</td>
<td>61.2</td>
<td>61.2</td>
<td>61.3</td>
<td>61.4</td>
</tr>
<tr>
<td>$K_2/Q^\infty$ (%)</td>
<td>95.6</td>
<td>91.7</td>
<td>90.2</td>
<td>89.2</td>
<td>86.7</td>
</tr>
<tr>
<td>$W'(\alpha)$ (€ millions/year)</td>
<td>981</td>
<td>681</td>
<td>620</td>
<td>592</td>
<td>533</td>
</tr>
<tr>
<td>$\delta W^-$ (€ /user/year)</td>
<td>12 129</td>
<td>8 419</td>
<td>268</td>
<td>13</td>
<td>6</td>
</tr>
<tr>
<td>$\delta W^+$ (€ /user/year)</td>
<td>12 129</td>
<td>294</td>
<td>14</td>
<td>6</td>
<td>$n/a$</td>
</tr>
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</table>
Cost of a real time meter estimated at €250, assumed independent of the characteristics of the site where the meter is installed, in particular peak-demand.

Assuming a cost of capital at 10%, the annualized cost of each meter is 25 €/meter/year.
Conclusion and next steps

- Preliminary analysis suggests switching to real time pricing generates net surplus from consumption estimated around 10 €/customer/year for small customers. If confirmed, this finding would challenge the smart meters business case for these customers.

- Additional analysis is required, that will:
  - develop and test other specifications for demand and uncertainty
  - apply to other markets
  - incorporate market power (Allcott (2010))