A Study on the Flexibility of Electricity Consumers for the Swedish Context – Modelling, Quantification and Analysis of Notice Time

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“Time is what we want most, but what we use worst.”

- William Penn (1644-1718)
Agenda

1. Motivation
   • Wind Power Forecast Horizon
2. Demand Response Programs
   • Notice Time
3. Modelling of flexible consumers
   • Demand Bidding with updates
4. Elasticity Review
5. Elasticity Results
6. Discussion & Conclusion
7. Outlook
1. Motivation
1. Motivation

- Renewable Energies
- Intermittent Production
- Uncertain Forecasts
1. Motivation: Wind Power Integration

- Wind power forecast accuracy:
  - Probability for more accurate forecasts improves
1. Motivation: Wind Power Integration
1. Motivation

Balancing in different time frames:

• Historically:
  • Hydro power
  • CCGT turbines
• Future:
  • Hydro
  • Storage (el., chem., etc..)
  • Demand Side
2. Demand Response Programs

- Market-based
- Dispatch-based
- Control-based
- **Time-based**

![Diagram showing different types of demand response programs]

**Price Based**
- Operational Planning
  - Time of Use
    - months

**Incentive Based**
- Capacity Market
- Ancillary Services

**Demand Response Programs**
- Economic Scheduling
  - Real Time Pricing
    - day-ahead

- Economic Dispatch
  - Critical Peak Pricing
    - intra-day
  - Emergency DR
    - Curtailable Load

- Real Time
  - Direct Control

8/31/2016
2. Demand Response: Notice Time

- Notice Time: time span between notification and delivery (Process Management: Order Lead Time)

<table>
<thead>
<tr>
<th>Demand Response Event</th>
<th>Deployment Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Notice Period(s)</td>
<td>Ramp Period</td>
</tr>
<tr>
<td></td>
<td>Sustained Response Period</td>
</tr>
<tr>
<td></td>
<td>Recovery Period</td>
</tr>
</tbody>
</table>

The stages of a Demand Response Event, adapted from: [Source: SEDC, “Mapping Demand Response in Europe Today,” 2014.]
2. Demand Response: Notice Time

- Assume $\varepsilon$ to decrease as notice time decreases
3. Continuously Updated Demand Bidding

<table>
<thead>
<tr>
<th>Time</th>
<th>Update</th>
<th>Notice</th>
<th>WP forecast</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>t</td>
<td>t_u</td>
<td>t_n</td>
<td>W_{fu}</td>
<td>\lambda_u</td>
</tr>
<tr>
<td>12:00</td>
<td>1</td>
<td>36h</td>
<td>W_{fl} \rightarrow G_1, D_{fl}</td>
<td>\lambda_1</td>
</tr>
</tbody>
</table>

\[ k_2 \cdot D_{f2} \rightarrow \lambda_2 \]

\[ k_3 \cdot D_{f3} \rightarrow \lambda_3 \]
### 3. Continuously Updated Demand Bidding

<table>
<thead>
<tr>
<th>Time (t)</th>
<th>Update (t_u)</th>
<th>Notice (t_n)</th>
<th>WP forecast</th>
<th>Price (λ_u)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12:00</td>
<td>1</td>
<td>36h</td>
<td>$W_{fu}$ $G_1$, $D_{f1}$</td>
<td>$λ_1$</td>
</tr>
<tr>
<td>18:00</td>
<td>2</td>
<td>30h</td>
<td>$W_{f2}$ $G_2$, $k_2 \cdot D_{f2}$</td>
<td>$λ_2$</td>
</tr>
<tr>
<td>24:00</td>
<td>3</td>
<td>24h</td>
<td>$W_{f3}$ $G_3$, $k_3 \cdot D_{f3}$</td>
<td>$λ_3$</td>
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<tr>
<td>6:00</td>
<td>4</td>
<td>18h</td>
<td>$W_{f4}$ $G_4$, $k_4 \cdot D_{f4}$</td>
<td>$λ_4$</td>
</tr>
<tr>
<td>12:00</td>
<td>5</td>
<td>12h</td>
<td>$W_{f5}$ $G_5$, $k_5 \cdot D_{f5}$</td>
<td>$λ_5$</td>
</tr>
<tr>
<td>18:00</td>
<td>6</td>
<td>6h</td>
<td>$W_{f6}$ $G_6$, $k_6 \cdot D_{f6}$</td>
<td>$λ_6$</td>
</tr>
<tr>
<td>23:00</td>
<td>7</td>
<td>1h</td>
<td>$W_{f7}$ $G_7$, $k_7 \cdot D_{f7}$</td>
<td>$λ_7$</td>
</tr>
<tr>
<td>24:00</td>
<td>8</td>
<td>0</td>
<td>$W_{\text{real}}$ $G_8$, $k_8 \cdot D_{f8}$</td>
<td>$λ_8$</td>
</tr>
</tbody>
</table>
3. Modelling

- Continuously Updated Demand Bidding: wind decrease
3. Modelling

- Continuously Updated Demand Bidding: wind increase
4. Elasticity Review

Estimated price elasticity
- Exclude non-price related effects

Own-price elasticity for instant response
- Estimated for the simple setups of Time-Of-Use pricing and the complex setups of Real-Time-Pricing.

<table>
<thead>
<tr>
<th>Time</th>
<th>00-06</th>
<th>06-08</th>
<th>08-10</th>
<th>10-16</th>
<th>16-18</th>
<th>18-20</th>
<th>20-00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elasticity</td>
<td>E1</td>
<td>E2</td>
<td>E3</td>
<td>E4</td>
<td>E5</td>
<td>E6</td>
<td>E7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time</th>
<th>Low</th>
<th>Peak Period</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elasticity</td>
<td>E1</td>
<td>E2</td>
<td>E1</td>
</tr>
</tbody>
</table>
4. Elasticity Review

Assumptions

1. Different approaches for elasticity estimation give similar results.
   - Difficult to find projects/articles with similar approaches and models from which elasticity has been estimated.
   - A general lack of published own-price elasticity estimates.

2. The relation between elasticity estimations from different setups tested in the same project should be similar to other projects.

3. Notice times described in phrases like “Day-ahead” can be associated with a certain number of hours.
4. Elasticity Review

In 2012/2013 EU’s Joint Research Center reported from 281 smart grid projects in 30 European countries. Only 65 (23%) of the projects involved consumer engagement.

- Projects have included up to 2000 participating consumers, generally biased towards volunteers with specific interest in this development.
- In the 65 consumer engaging projects in Europe two projects included any version of the word ELASTICITY in the project description.
  - Commercial and industrial consumer
4. Elasticity Review

Summary of results from residential US DR-pilots (Shariatzadeh et al., 2015): Maximum peak reductions percentages reached

- Avg. for projects including technological assistance: 38 %
- Avg. for projects without technological assistance: 27 %

- Avg. for Critical Peak Pricing: 34 %
- Avg. for Time Of Use pricing: 17 %
- Avg. for Real Time Pricing: 16 %

There are apparent benefits for certain program setups!
4. Elasticity Review

**PREVIOUS PROJECTS:** A search on Google Scholar for PRICE ELASTICITY ELECTRICITY ”DEMAND RESPONSE” has almost 7000 results

- Early studies (1977-2000) on the “close-to-hourly” price elasticity of households’ electricity consumption seem to have been dominated by Time-Of-Use (TOU) pricing projects.
- Lately Critical-Peak-Pricing (CPP) and Real-Time-Pricing (RTP) have taken over the scene.
- **Concluded:** residential consumers have lower own-price elasticity for RTP-programs than for TOU pricing, a result of information costs. (1)
- **Difficult to compare the results and price elasticity estimates from these different projects**
4. Elasticity Review

"Notice time"-dependent elasticity

- TOU has a static/indefinite notice time,
- CPP and RTP use different notice times depending on DR-program structure.
- Emphasis in articles on presenting notice times and description of the standards for the communication with consumers has been low.

Objective for this study:

- Gather the results from at least 15 DR-projects spread over the three types of pricing for DR-programs, where the notice time is explicitly presented.
- Analyze the possible relation between notice time and own-price elasticity.
5. Elasticity Results

From California SPP (Faruqui, 2005):

1. Adding assisting technology to DR-program: +15% (more elastic)
2. Changing from static to day-ahead notice time: -34% (less elastic)
3. Changing from static to day-of notice time: +18% (more elastic)

Other pilots with multiple DR-programs:

• (1) is supported by findings in NJ PSE&G RPP (Faruqui and Sergici, 2010)
• (3) is supported by findings in Washington GOPP (Hammerstrom, 2007)
5. Elasticity Results

![Graph showing elasticity results over notice time](image-url)
5. Elasticity results

Averages without elasticity estimates from old projects (before 2000):

- Avg. for all projects: -0.25
- Avg. for projects including technological assistance: -0.11
- Avg. for projects without technological assistance: -0.20
- Avg. for static notice time: -0.34
- Avg. for day-ahead notice time: -0.03
- Avg. for day-of notice time: -0.11

- Not the hypothesized effect from technology…!
5. Elasticity Results

![Graph showing own price elasticity over notice time in hours. The graph compares Time of Use, Day Ahead, Intra Day, and Approximation scenarios. The x-axis represents notice time in hours, ranging from 0 to 168, and the y-axis represents own price elasticity, ranging from -0.8 to 0.]
6. Discussion & Conclusion - Elasticity

How can comparability be assured in price elasticity estimation for DR-projects?

• Challenges
  – Hourly or averages for all peak hours
  – Exogenous causes for demand increase
  – Different price ratios

• Suggestion
  – Presenting detailed results hourly within the peak hours.
6. Discussion & Conclusion

CU-DB model:

• Enables consumers to be updated & participate
• Consumers in competition with flexible generation in forward markets
• Opens the opportunity for both bidding parties to increase their utility in consecutive market places
• Risk of deterministic consumers is minimized
• Wind power producers may exploit market power by strategically bidding with a lowered wind power forecast
7. Outlook

- In CU-DB model: both forecast error magnitude and notice time affect the market equilibrium

<table>
<thead>
<tr>
<th>Forecast Error</th>
<th>Static Tariffs</th>
<th>Day-Ahead</th>
<th>Intra-Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very High (&gt;10%)</td>
<td>High (10-5%)</td>
<td>Medium to Low (5-1%)</td>
<td></td>
</tr>
<tr>
<td>Demand Elasticity</td>
<td>Medium</td>
<td>Lower</td>
<td>Higher</td>
</tr>
</tbody>
</table>

- Market with updates can be beneficial for improved integration of renewables.
7. Outlook
Thank you

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