Empirical Analysis of the Spot Market Implications of Price-Elastic Demand

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by

Afzal Siddiqui
University College Dublin

afzal.siddiqui@ucd.ie  -  +353.1.716.8091

Co-authors: Emily Bartholomew (Berkeley Lab) and Chris Marnay (Berkeley Lab)

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Outline

• Background and Objective
• Theory of Price-Elastic Demand
• Overview of New York Control Area
• Empirical Methodology and Results
• Conclusions
Background

- **Vertical integration:** all electricity functions provided by regulated investor-owned utility (IOU)

- **Deregulation:** introduction of competition into sectors of the electricity industry that are amenable to it

- This has resulted in divestiture of IOUs’ generation assets

- In the U.S., deregulation process has separated the sectors with “natural monopoly” characteristics from the competitive ones

- Transmission sector to be controlled by independent system operator (ISO)
Objective

- Most of the effort has been directed towards the supply side with few demand-side initiatives
- Deregulated electricity markets, therefore, differ from others for commodities because end-use consumers are still subject to constant retail rates
- End-users do not perceive real-time fluctuations in the wholesale price
- Consequently, they are unable to adjust their consumption accordingly
- Theoretically, price elasticity is desirable, but how much of an impact would it make?
- Use data from New York market to quantify the benefits of price elasticity from a policymaking perspective
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Theory of Price-Elastic Demand

\[ Q_s(p) \]

\[ Q_{d0}(p) \]

\[ Q_{d1}(p) \]

\[ Q_{d2}(p) \]

\[ q_0 \]

\[ q_1 \]

\[ q_2 \]

\[ p_0 \]

\[ p_1 \]

\[ p_2 \]

\[ p^* \]

\[ q^* \]

\[ 1/b \]
Theory of Price-Elastic Demand

- Definition of price elasticity: 
  \[ \eta(p^*, q^*) = \frac{p^* \frac{\partial Q_d}{\partial p}}{q^* \frac{\partial Q_d}{\partial p}} \]

- Linear inverse-demand specification: 
  \[ Q_d(p) = a - bp \]
  where \(a > 0\) and \(b > 0\), then
  \[ \eta(p, q) = \frac{p}{q} b \]

- If both demand and supply are linear, then what are the comparative statics resulting from changes in \(b\)?

- Both the equilibrium price and quantity decrease, but at a diminishing rate:
  \[ \frac{\partial p}{\partial b} < 0 \quad \frac{\partial^2 p}{\partial b^2} > 0 \quad \frac{\partial q}{\partial b} < 0 \quad \frac{\partial^2 q}{\partial b^2} > 0 \]

- Implication: do not need much elasticity in order to have an effect

- Try to quantify this feature for the New York industry
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New York Control Area

- New York ISO (NYISO) manages the entire grid in the state and operates markets that provide half of the electricity
- State is divided up into eleven congestion zones, each of which consists of many generation buses
- Locational-based marginal price (LBMP) is calculated for each zone and bus
- LBMP depends on intersection of supply offer and demand bid stacks
- We construct generator offer stacks by adding individual ones horizontally
- Assume no congestion or demand-side response
New York Control Area
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Methodology

- Objective: use NYISO data for year 2002 to construct hourly supply stacks and determine the potential impact of real-time pricing

- In effect, calculate $\frac{\partial p}{\partial b}$, $\frac{\partial^2 p}{\partial b^2}$, $\frac{\partial q}{\partial b}$, and $\frac{\partial^2 q}{\partial b^2}$.
Methodology

• By how much to increase the slope at each increment?

\[ 0 = b_0 < b_1 < \cdots < b_i < \cdots < b_{n-1} = \min \left\{ b \left| a - bp = \min_p Q_s (p) \right. \right\} \]

\[ b_j = \min \left\{ b \left| \frac{a - k_{n-j}}{b} = c_{n-j} \right. \right\} \Rightarrow b_j = \frac{a - k_{n-j}}{c_{n-j}}, 1 \leq j \leq n - 1 \]

• If the supply stack’s step sizes are small enough, then the increments to the slope are also small

• Allows approximate calculation of the slopes \( \frac{\partial p}{\partial b} \) and \( \frac{\partial q}{\partial b} \):

\[ \left. \frac{\partial p}{\partial b} \right|_{(p_i^*, q_i^*)} = \lim_{\Delta b_i \to 0} \frac{\Delta p_i^*}{\Delta b_i} \approx \frac{p_i^* - p_{i-1}^*}{b_i - b_{i-1}}, i = 0, \ldots, n - 1 \]

\[ \left. \frac{\partial q}{\partial b} \right|_{(p_i^*, q_i^*)} = \lim_{\Delta b_i \to 0} \frac{\Delta q_i^*}{\Delta b_i} \approx \frac{q_i^* - q_{i-1}^*}{b_i - b_{i-1}}, i = 0, \ldots, n - 1 \]
Methodology

NYISO Supply Stack for 08 August 2002 (1400)
Results

Effect of Demand Elasticity on the Market-Clearing Price

Market-Clearing Price ($/MWh)

Elasticity
Results

Effect of Demand Elasticity on the Market-Clearing Quantity

Market-Clearing Quantity (MW)

Elasticity

0 100 200 300 400 500

0 5000 10000 15000 20000 25000
## Results

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Average Elasticity Required</th>
<th>Standard Deviation of Required Elasticity</th>
<th>Corresponding Average Demand (MW)</th>
<th>Average Percentage Decrease in Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>25% Decrease in Price</td>
<td>0.23</td>
<td>0.12</td>
<td>13004</td>
<td>18%</td>
</tr>
<tr>
<td>50% Decrease in Price</td>
<td>0.53</td>
<td>0.19</td>
<td>10411</td>
<td>34%</td>
</tr>
<tr>
<td>75% Decrease in Price</td>
<td>0.87</td>
<td>0.31</td>
<td>8483</td>
<td>46%</td>
</tr>
</tbody>
</table>
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Conclusions

- Deregulated electricity industries suffer from a lack of demand-side response

- Attempt to quantify the effect of real-time pricing on the equilibrium prices and quantities in the NYISO control area for year 2002

- Results confirm the diminishing marginal returns of elasticity

- Most of the feasible potential reductions in the price can be achieved at levels of elasticity that are exhibited by large consumers

- Directions for future research: non-linear demand curves, supply shocks, forward market implications of real-time pricing