WELFARE EFFECT OF MARKET POWER IN STORAGE

Olayinka Williams and Richard Green
Energy Storage

• Energy storage devices can provide much needed flexibility

• Economic benefits of storage
  – Delay transmission and distribution upgrades,
  – Balancing services
  – Congestion relief
  – Reduce the cost of electricity generation
  – Integration of renewables

• Storage usage
  – Maximize social welfare (socially optimal operation)
  – Maximize Profits (strategic operation)
Energy Storage

• Strategic operation of Storage
  – Price spread manipulation
  – Starting and shutting off Generators
  – Welfare transfers/losses

• Interaction with strategic generators
  – Generator market power mitigation
  – Collusion
Start Costs

• Fluctuation in demand and renewables
  — Generator start
  — Generator shut down

• Start Cost
  — Fuel consumption necessary before generation

• Start costs must be recovered
  — Rolled into marginal cost (United Kingdom)
  — Presented with bid (Nodal system)
Literature

• Market power and energy market
  – Green and Newbery (1992), Borenstein and Bushnell (1999)

• Market power and hydro

• Market power and Storage
Objectives

• What welfare effects will strategic operation of storage have in the presence of competitive generators?

• What welfare effects will storage have in the presence of strategic generators?
General Approach

• Simulation of non-linear program
  – GAMS 24.7

• The use of sample days
  – Obtained by clustering (see Green et al, 2014)

• Merit Order stack with start heuristics
  – Staffell and Green (2016)
The Merit Order Stack

£/MWh

Marginal Cost of Generation

P3

P2

P1

GW
Start Costs Heuristic

\[ MC_{g,t} = MC_g + \text{start cost} \]

\[ MC_{g,t} = MC_g + \frac{\text{start cost}}{7 \text{ hours on}} \]

\[ MC_{g,t} = MC_g - \frac{\text{start cost}}{8 \text{ hours off}} \]

\[ MC_{g,t} = MC_g - \text{start cost} \]
A Competitive Generator

\[
(P_t - MC_{g,t})(Capacity_g - output_{g,t}) \leq 0
\]

\[
(P_t - MC_{g,t})output_{g,t} \geq 0
\]
A Strategic Generator

\[(MR_t - MC_{g,t})(\text{Capacity}_g - \text{output}_{g,t}) \leq 0\]

\[(MR_t - MC_{g,t})\text{output}_{g,t} \geq 0\]
Data

• Load Data
  – National Grid

• Renewable load factors
  – Weather data from NASA's MERRA database
  – Virtual wind farm (Pfenninger and Staffell (2016))

• Generator Costs
  – Green and Staffell(2014)
Competitive Generation

£/MWH

Hours

-120 -70 -20 30 80 130

1 6 11 16 21

No Storage 5GW competitive

Imperial means Intelligent Business
Competitive Generation

£/MWH

Hours

-120 -70 0 30 80 130

6 11 16 21

No Storage  5GW competitive  5GW Market power
Competitive Generation

£/MWH

No Storage  5GW competitive  5GW Market power  10GW competitive

Imperial means Intelligent Business
Competitive Generation

£/MWH

Hours

No Storage  5GW competitive  5GW Market power  10GW competitive  10GW Market power

Imperial means Intelligent Business
Impact of market power in storage (with competitive Generation)
Impact of market power in storage (with competitive Generation)

Price Difference

Market power - competitive (5GW)
Market power - competitive (10GW)
Impact of market power in storage (with competitive Generation)
Strategic Generation

£/MWH

No Storage
Price differential with Strategic Generation

Price differentials

Hours

Market power - competitive (5GW)
# Welfare Effects (Competitive Generators)

<table>
<thead>
<tr>
<th>Storage</th>
<th>Welfare (Welfare/Turnover)</th>
<th>Consumer Surplus (£/millions)</th>
<th>Generator profit (£/millions)</th>
<th>Storage Profit (£/millions)</th>
<th>Energy Discharged (GWH)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5GW, 20GWh</td>
<td>-0.04</td>
<td>-221</td>
<td>154</td>
<td>56</td>
<td>-45</td>
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<tr>
<td>10GW, 40GWh</td>
<td>-0.05</td>
<td>-429</td>
<td>225</td>
<td>203</td>
<td>-120</td>
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<tr>
<td>5GW, 40GWh</td>
<td>-0.06</td>
<td>-318</td>
<td>250</td>
<td>56</td>
<td>-75</td>
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# Welfare Effects (Strategic Generators)

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</thead>
<tbody>
<tr>
<td>5GW, 20GWh</td>
<td>-0.0005</td>
<td>-634</td>
<td>72.9</td>
<td>376.7</td>
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<tr>
<td>10GW, 40GWh</td>
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<td>-875.5</td>
<td>1,396.4</td>
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<tr>
<td>5GW, 40GWh</td>
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<td>-847.9</td>
<td>197.5</td>
<td>430.5</td>
<td>-4,169</td>
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</tbody>
</table>
Concluding Remarks

• Strategic operation has marginal effects on welfare/turnover ratio.

• Higher power rating will amplify loses from strategic storage operation.

• Strategic generators can lose when storage is operated strategically.

• Socially optimal operation of a very large storage device might not be sustainable.
Any questions?
References


References