Welfare implications of capacity markets in the electricity sector

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“Electricity markets: ‘Best practice’ and restructuring in Asia”

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Introduction

- 90’s privatization process: competitive electricity markets
  - Electricity generators = private firms

- \( E(\text{revenue}) = \text{total cost of investment} \)

- But regulators introduced price caps (\( p\) cap)
  - Maximum price at which generators can sell electricity

- The "missing money" problem
  - Expected revenues from sales of energy at market prices are insufficient for generators to invest in new capacity
  - Joskow (2008)

- System fails to attract investment in generation capacity sufficient to meet system operators' reliability objectives
Electricity
Generators
"The Big Picture"

- Electricity Generators
- Invest in Generation Capacity
“The Big Picture”

Electricity Generators → Customers

Invest in Generation Capacity

provide electricity
“The Big Picture”

1. **Electricity Generators**
   - Invest in Generation Capacity
   - Provide electricity
   - Pay the price

2. **Customers**
   - Fund the Investment made by Generators

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Capacity markets (V Asia IAEE, Perth)
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A potential solution: Capacity Markets

Capacity markets

- Goal: provide right financial incentives for building power generation capacity

- Regulator establishes a capacity requirement
  - Capacity requirement = E(peak demand) + reserve margin
  - Generators compete to achieve requirement (e.g. via auction)
  - Generators receive a capacity compensation (a payment)
Where are capacity markets implemented?

- Outside the US we find capacity markets in the UK, Western Australia, Italy, France, Colombia...
Outside the US capacity markets have been rejected in Germany, Australia’s NEM, Alberta...
Capacity Markets controversy

● Arguments for
  
  - Investment incentives would be inadequate without them. Solve the missing money problem (Joskow 2008)
  - Mitigate withholding risk, reduce market power in the spot market (Ausubel and Cramton 2010)

● Arguments against
  
  - Little connection between capacity markets and real time spot market operations (Hogan 2013)
  - “Putative product” of capacity markets is hard to price and measure (Hogan 2013)
  - Increase average electricity price (Kleit and Michaels 2013)
Research Question

How much do consumers gain by implementing a capacity market in a competitive electricity sector?

- Case study: Texas ERCOT
  - “Energy-only” market with price caps
  - Facing the underinvestment problem
ERCOT’s forecasted capacity reserves (2011)

Price Cap in 2011: $2,500/MWh

Source: ERCOT’s website
Model assumptions

Demand

- Continuum of consumers
- Reservation price (VOLL)
- Stochastic aggregate market demand
- Rotated “L”
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![Graph showing demand curve with p on the y-axis and q on the x-axis.](image-url)
Model assumptions

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- Reservation price (VOLL)
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**Supply**
- Firms (risk neutral)
  - base load generators (e.g. coal)
  - peak load generators (e.g. natural gas)
- Variable Costs:
  - base < peak
- Per-unit Capacity Costs:
  - base > peak
- Generation above capacity is impossible
Market timing

1. Each generator decides how much to invest in capacity

2. Generators compete in a centralized market (auction) to sell electricity

Solve by Backward Induction
Market timing

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   Find equilibrium bids and market outcome

Solve by Backward Induction
Each generator decides how much to invest in capacity

Find *equilibrium investment* in capacity for *two scenarios*:

(a) W/o capacity compensation  (b) W/ capacity compensation

Generators compete in a centralized market (auction) to sell electricity

Find *equilibrium bids* and market outcome

Solve by Backward Induction
Evaluate model using ERCOT data

- ERCOT hourly load data (in MW) 1996-2014 (n=145,762)
  - Subtract nuke generation (as running 24/7)
  - Subtract the wind, hydro and biomass generation (small)

- Additional parameters:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Model parameter</th>
<th>Actual parameter (2011)</th>
<th>Source</th>
<th>Data ($/MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$p^H$</td>
<td>Value of Lost Load (reservation price)</td>
<td>ERCOT’s Estimated VOLL</td>
<td>Frayer et al. (2013)</td>
<td>6,000</td>
</tr>
<tr>
<td>$p^{cap}$</td>
<td>Price Cap</td>
<td>System-wide Offer Cap</td>
<td>ERCOT</td>
<td>2,500</td>
</tr>
<tr>
<td>$c_b$</td>
<td>Base load variable cost</td>
<td>Heat rate, fuel cost, O&amp;M</td>
<td>EIA and ERCOT</td>
<td>24.5</td>
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<td>$c_{b_{kap}}$</td>
<td>Base load per-unit capacity cost</td>
<td>Levelized cost of capital</td>
<td>EIA</td>
<td>63.0</td>
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<td>$c_{p_{kap}}$</td>
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<td>Levelized cost of capital</td>
<td>EIA</td>
<td>45.8</td>
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Main Results

- Raising/eliminating the price cap:
  - Increases investment in generation capacity
ERCOT’s forecasted capacity reserves (2011)

Price Cap in 2011: $2,500/MWh

Source: ERCOT’s website
ERCOT’s forecasted capacity reserves (2012)

Price Cap in 2012: $4,500/MWh

Target Reserve Margin (13.75%)

Source: ERCOT’s website
ERCOT’s forecasted capacity reserves (2013)

Price Cap in 2013: $5,000/MWh

Source: ERCOT’s website

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Capacity markets (V Asia IAEE, Perth)
ERCOT’s forecasted capacity reserves (2014)

Price Cap in 2014: $7,000/MWh

Source: ERCOT’s website

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Capacity markets (V Asia IAEE, Perth)
Main Results

- Raising/eliminating the price cap:
  - Increases investment in generation capacity
  - But at the cost of raising price volatility
Price volatility skyrockets

Market Clearing Prices in $/MWh in Texas ERCOT (09/03/2013)

Source: Acclaim Energy
Price volatility skyrockets

Market Clearing Prices in $/MWh in Texas ERCOT (09/03/2013)

Recall... the price Cap in 2013: $5,000/MWh

Source: Acclaim Energy
Price volatility skyrockets

ERCOT Load and Real-time prices (01/06/2014)

Source: Morningstar
Main Results

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  - Lead us to the efficient result (first-best)
Main Results

- **Raising/eliminating the price cap:**
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- **Introducing a capacity compensation (capacity market):**
  - Solves the underinvestment problem while allowing price caps (reduces price volatility)
Maximum Real-Time Price of Electricity (01/06/2014)

Source: ICF International
Price Volatility? Just in ERCOT!

Maximum Real-Time Price of Electricity (01/06/2014)

Source: ICF International
Percent Increase on Real-Time Electricity and Natural Gas Prices (01/06/2014)

Source: ICF International
Main Results

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• Introducing a capacity compensation (capacity market):
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  - But increase on average electricity prices: insurance effect
Additional points for further discussion...

- **Wind capacity penetration**
  - Intermittency issues
  - Wind usually blows at night (displaces base load)
  - Capacity markets become even more necessary

- **Capacity market regulation**
  - Auctions (mandatory?) vs. bilateral agreements
  - Price-based vs. quantity based mechanisms

- **Connecting the capacity market and the “energy” markets**
  - How far away in time?
  - Compensation for strategic reserves?
Thanks!

Your feedback is highly appreciated: raulbajob@rice.edu

Acknowledgements