Electricity Market Restructuring, Grid Reliability, and Nuclear Power Plant Safety in the United States

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Nuclear Plant Electrical Power System
What happened in Fukushima
Electric Power from Transmission Grid

- **Preferred** source of electric power to nuclear power plant
- **Grid Reliability** from the viewpoint of nuclear plants
  - Un-interrupted electric power supply
  - Stable voltage and frequency, controlled in a narrow range

- **So, when something wrong occurred over the transmission grid...**
Reactor Trip (Emergency Shutdown)
Consequential Loss of Offsite Power
Direct Loss of Offsite Power
Safety Implication

- Reactor Trip
  - Plant in “upset” condition
- Loss of Offsite Power (LOOP)
  - Precursor to Station Blackout, a significant contributor to reactor core damage

- Reduce the frequency of reactor trip / LOOP
U.S. Electricity Market Restructuring

• Traditional Vertically Integrated Market

• Electricity Market Restructuring

Source: National Energy Education Development Project (Public Domain)
Possible Effects on Grid Reliability

- may increase power flow disturbance
  - Power transmitted over longer distance with unprecedented volume
- may increase human errors
  - Additional interface
  - Outsourcing / downsizing
- may increase transmission equipment malfunctions or failures
  - Reduced maintenance
Research Question

Does the frequency of reactor trips/LOOPs increase in competitive markets

Grid Reliability
Nuclear Plant Safety
Data

- Licensee Events Report
  - 1990 to 2011
  - Reactor trips/LOOPs due to disturbance/faults over transmission grid
    - Causes of transmission grid faults
    - Season
Empirical Strategy

- Multi-failure duration analysis with time-varying regressors
  - Events are sparsely distributed
- Empirical Specification
  - Cox Proportional Regression
  - \( h_i(t) = h_{0,i}(t) \exp(X_{i,t}\beta + \varepsilon_{i,t}) \)
  - \( X_{i,t}\beta = \beta_1 \text{Market}_{i,t} + \beta_2 \text{Transition}_{i,t} + \beta_3 \text{GridStress}_{i,t} + \beta_4 \text{Upgrade}_{i,t} + \beta_5 \text{Characteristic}_{i,t} + \gamma Year_t \)
## Empirical Results – by event causes

<table>
<thead>
<tr>
<th>[Market]</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reactor Trips caused by power flow disturbance</td>
<td></td>
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<tr>
<td>Transition</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Grid Stress</td>
<td>X</td>
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<tr>
<td>Reactor Upgrade</td>
<td></td>
<td></td>
<td>X</td>
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<tr>
<td>Reactor Characteristics</td>
<td></td>
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</tbody>
</table>
## Empirical Results – by season

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</tr>
</thead>
<tbody>
<tr>
<td>Events occurred during summer</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>[Market]</td>
<td>3.335** (1.557)</td>
<td>6.308*** (3.014)</td>
<td>5.932*** (2.906)</td>
<td>5.778*** (2.838)</td>
</tr>
<tr>
<td>Transition</td>
<td>X</td>
<td>X</td>
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Results and Policy Implications

• Reactors in competitive markets are more likely to trip due to power flow disturbance over transmission grid, particularly during summer months (May to September)

• Implications
  • Grid reliability at transmission level
  • Operation safety of current nuclear plants
Thank you for your attention