Keeping the lights on until the regulator makes up his mind

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Test real options theory

- The real option to...
  - Shutdown
  - Startup
  - Abandon
Results

- Single most important driver of status changes is **expected future profitability**.
- **High expected profitability →**
  - Fewer shutdowns & abandonments.
  - More startups.
- **Low expected profitability →**
  - More shutdowns & abandonments.
  - Fewer startups.
Results

Profit margin uncertainty
- Important for shutdown and abandonment.
- Important for startups. (But not for small plants.)
  - Higher spark spread volatility $\rightarrow$ more startups.

Regulatory uncertainty
- Reduces/delays status changes
  - More uncertainty $\rightarrow$ fewer shutdowns
  - More uncertainty $\rightarrow$ fewer startups
  - No significant effect on abandonments
The real options problem

Switching costs
- Shutdown cost, restart cost, maintenance costs and salvage value

Assume that the switching decisions are made as a function of profitability state variable and occur instantly

Assume time invariance

Three value-matching and three smooth-pasting conditions
Sample period 2001-2009
- EIA 860 (data source) format changes in 2001
- Focus on peaking plants (CTs)
  - Natural gas and #2 oil
Final sample:
- 1,121 unique plants
- 8,189 plant-year observations
Table I – Plant summary statistics

<table>
<thead>
<tr>
<th></th>
<th>Age (years)</th>
<th>Size (MW)</th>
<th>Eff. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOBS</td>
<td>1,121</td>
<td>1,121</td>
<td>1,121</td>
</tr>
<tr>
<td>Mean</td>
<td>18.6</td>
<td>43.1</td>
<td>24.7%</td>
</tr>
<tr>
<td>Stdev</td>
<td>14.1</td>
<td>41</td>
<td>4.6%</td>
</tr>
<tr>
<td>Min</td>
<td>0</td>
<td>0.4</td>
<td>5.4%</td>
</tr>
<tr>
<td>Max</td>
<td>60</td>
<td>246</td>
<td>41.8%</td>
</tr>
</tbody>
</table>
➤ **Status code**

- **OP** – operating
- **SB** – on standby (mothballed/shutdown)
- **RE** – retired
## Shutdown occurrences

<table>
<thead>
<tr>
<th>from year</th>
<th>to year</th>
<th>OP</th>
<th>SB</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>2002</td>
<td>695</td>
<td>2</td>
<td>697</td>
</tr>
<tr>
<td>2002</td>
<td>2003</td>
<td>803</td>
<td>1</td>
<td>804</td>
</tr>
<tr>
<td>2003</td>
<td>2004</td>
<td>808</td>
<td>43</td>
<td>851</td>
</tr>
<tr>
<td>2004</td>
<td>2005</td>
<td>820</td>
<td>12</td>
<td>832</td>
</tr>
<tr>
<td>2005</td>
<td>2006</td>
<td>829</td>
<td>16</td>
<td>845</td>
</tr>
<tr>
<td>2006</td>
<td>2007</td>
<td>848</td>
<td>0</td>
<td>848</td>
</tr>
<tr>
<td>2007</td>
<td>2008</td>
<td>851</td>
<td>2</td>
<td>853</td>
</tr>
<tr>
<td>2008</td>
<td>2009</td>
<td>885</td>
<td>0</td>
<td>885</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>6,539</td>
<td>76</td>
<td>6,615</td>
</tr>
</tbody>
</table>
## Startup & abandonment

<table>
<thead>
<tr>
<th>from year</th>
<th>to year</th>
<th>OP</th>
<th>SB</th>
<th>RE</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>2002</td>
<td>60</td>
<td>221</td>
<td>1</td>
<td>282</td>
</tr>
<tr>
<td>2002</td>
<td>2003</td>
<td>47</td>
<td>198</td>
<td>1</td>
<td>246</td>
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<tr>
<td>2003</td>
<td>2004</td>
<td>9</td>
<td>143</td>
<td>49</td>
<td>201</td>
</tr>
<tr>
<td>2004</td>
<td>2005</td>
<td>22</td>
<td>153</td>
<td>13</td>
<td>188</td>
</tr>
<tr>
<td>2005</td>
<td>2006</td>
<td>1</td>
<td>158</td>
<td>6</td>
<td>165</td>
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<tr>
<td>2006</td>
<td>2007</td>
<td>6</td>
<td>173</td>
<td>0</td>
<td>179</td>
</tr>
<tr>
<td>2007</td>
<td>2008</td>
<td>32</td>
<td>139</td>
<td>2</td>
<td>173</td>
</tr>
<tr>
<td>2008</td>
<td>2009</td>
<td>7</td>
<td>127</td>
<td>6</td>
<td>140</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>184</td>
<td>1,312</td>
<td>78</td>
<td>1,574</td>
</tr>
</tbody>
</table>
 Reserve margin

\[ RM_{kt} = \frac{(C_{kt} - D_{kt})}{D_{kt}} \]

- \( RM_{kt} \) – reserve margin
- \( C_{kt} \) – capacity (year t, region k)
- \( D_{kt} \) – demand

Proxy for future profitability

- Low RM – high electricity prices – high future profitability
- High RM – low electricity prices – low future profitability
Spark Spread ($/MWh)

$$SPRD \downarrow_{ijkn} = PE_{kn} - HR_i \cdot PF_{jn} - VOM_i$$

- $PE_{k,n}$ = day $n$ elec price in region $k$
- $HR_i$ = heat rate for plant $i$
- $PF_{j,n}$ = day $n$ fuel price for fuel $j$
- $VOM_i$ = variable O&M costs for plant $i$
Electricity prices ($/MWh)

- Three markets
  1. New England (ISO-NE)
  2. Pennsylvania-NJ-Maryland (PJM)
  3. New York (NYISO)

- Approximately upper right quadrant of US

- Average daily peak price
  - Hours Ending 07:00 - 22:00

Source: ISO-NE, PJM, NYISO websites
Fuel prices ($/MMBtu)

- Daily spot prices
  - NY Harbor No. 2 Oil
  - Henry Hub Natural Gas

Source: EIA website

http://www.eia.gov/petroleum/data.cfm
http://www.eia.gov/naturalgas/data.cfm
Spark spread volatility

$$SPRDSD_{it} = Stdev \left( SPRD_{in} \right)$$

- $Stdev$ taken over days of previous year
  $n=1,T$
Plants = options

- Power plants are (a series of) call options on the spark spread

- An increase in volatility increases the option value of the plant.
  - Fewer shutdowns & abandonments.
  - More startups.
State-Level retail competition index

1. No activity
2. Investigation underway
3. Competition recommended
4. Law passed
5. Competition implemented

Source: EIA; State Utility Commissions
Regulatory uncertainty indicator

- $\textit{REGUNCERT} = 0$
  - When competition index = 1, 4, 5

- $\textit{REGUNCERT} = 1$
  - When competition index = 2, 3
Regulatory uncertainty

- Likely to reduce the probability of any status change.
  - Fewer shutdowns
  - Fewer startups
  - Fewer abandonments
Shutdown Binary Logit Regression

- Plant \( i \) (which is operating in year \( t \))
- Fuel \( j \)
- Region \( k \)

Define

\[
I_{i,t+1}^{SB} = \begin{cases} 
0 & \text{if plant } i \text{ is operating in year } t+1 \\
1 & \text{if plant } i \text{ is on standby in year } t+1 
\end{cases}
\]
Table VI – Shutdown estimation results

\[ I_{t,t+1}^{SB} = \alpha + (\beta_1 \cdot RM_{k,t+1}) + (\beta_2 \cdot T10_t) + (\beta_3 \cdot EFF_t) + (\beta_4 \cdot SIZE_t) + (\beta_5 \cdot TOTCAP_t) \]
\[ + (\beta_6 \cdot SPRDS_{ij,t}) + (\beta_7 \cdot REGUNCERT_t) + \varepsilon, \]

(5)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>t-value</th>
<th>p-value</th>
<th>2nd Coefficient</th>
<th>Standard Error</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RM</td>
<td>0.252</td>
<td>0.001</td>
<td>74.1</td>
<td>0.000</td>
<td>0.235</td>
<td>0.001</td>
<td>85.6</td>
<td>0.000</td>
</tr>
<tr>
<td>T10</td>
<td>-0.902</td>
<td>0.010</td>
<td>-79.2</td>
<td>0.000</td>
<td>0.799</td>
<td>0.010</td>
<td>79.2</td>
<td>0.000</td>
</tr>
<tr>
<td>EFF</td>
<td>-0.064</td>
<td>0.015</td>
<td>-4.4</td>
<td>0.000</td>
<td>-0.047</td>
<td>0.015</td>
<td>-3.12</td>
<td>0.002</td>
</tr>
<tr>
<td>SIZE</td>
<td>-0.133</td>
<td>0.026</td>
<td>-5.1</td>
<td>0.000</td>
<td>-0.052</td>
<td>0.026</td>
<td>-2.01</td>
<td>0.045</td>
</tr>
<tr>
<td>TOTCAP</td>
<td>-1.718</td>
<td>0.234</td>
<td>-7.3</td>
<td>0.000</td>
<td>-1.416</td>
<td>0.234</td>
<td>-6.03</td>
<td>0.000</td>
</tr>
<tr>
<td>SPRDS</td>
<td>-1.016</td>
<td>0.234</td>
<td>-4.4</td>
<td>0.000</td>
<td>-0.609</td>
<td>0.234</td>
<td>-2.60</td>
<td>0.009</td>
</tr>
<tr>
<td>REGUNCERT</td>
<td>0.014</td>
<td>0.002</td>
<td>6.2</td>
<td>0.000</td>
<td>0.012</td>
<td>0.002</td>
<td>5.61</td>
<td>0.000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Value</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(R^2)</td>
<td>14.3%</td>
<td>22.6%</td>
</tr>
<tr>
<td>Log-likelihood</td>
<td>-355.8</td>
<td>-321.0</td>
</tr>
<tr>
<td>AIC</td>
<td>715.6</td>
<td>658.1</td>
</tr>
<tr>
<td>BIC</td>
<td>729.2</td>
<td>712.5</td>
</tr>
</tbody>
</table>
Startup & abandonment multinomial logit regression

- Plant $i$ (which is on standby in year $t$)
- Fuel $j$
- Region $k$

Define

$$I_{i,t+1}^{OPRE} = \begin{cases} 
0 & \text{if plant } i \text{ is operating in year } t+1 \\
1 & \text{if plant } i \text{ is on standby in year } t+1 \\
2 & \text{if plant } i \text{ is retired in year } t+1
\end{cases}$$
Table VIII – Startup & abandonment estimation

\[ I_{t,t+1}^{\text{OPRE}} = \alpha + (\beta_1 \cdot RM_{k,t+1}) + (\beta_2 \cdot T10_t) + (\beta_3 \cdot EFF_t) + (\beta_4 \cdot SIZE_t) + (\beta_5 \cdot TOTCAP_t) + (\beta_6 \cdot SBTIME_{i,t}) + (\beta_7 \cdot SPRDSD_{ijk,t}) + (\beta_8 \cdot REGUNCERT_t) + \varepsilon, \]  

(6)

<table>
<thead>
<tr>
<th>Startup</th>
<th>RM</th>
<th>T10</th>
<th>EFF</th>
<th>SIZE</th>
<th>TOTCAP</th>
<th>SBTIME</th>
<th>SPRDSD</th>
<th>REGUNCERT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-0.835***</td>
<td>7.764***</td>
<td>0.542**</td>
<td>1.117***</td>
<td>-4.064*</td>
<td>-0.039***</td>
<td>1.725***</td>
<td>-0.046</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Abandon</th>
<th>RM</th>
<th>T10</th>
<th>EFF</th>
<th>SIZE</th>
<th>TOTCAP</th>
<th>SBTIME</th>
<th>SPRDSD</th>
<th>REGUNCERT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.057***</td>
<td>-4.469***</td>
<td>-0.588***</td>
<td>-2.664***</td>
<td>10.965***</td>
<td>0.002</td>
<td>-3.229***</td>
<td>-0.033**</td>
</tr>
</tbody>
</table>

| pseudo-R² | 9.6% | 3.6% | 1.9% | 4.4% | 7.8% | 4.6% | 2.7% | 0.3% | 29.0% |
| Log-likelihood | -784.5 | -836.9 | -852.0 | -830.3 | -800.8 | -828.7 | -845.0 | -865.3 | -616.1 |
| AIC       | 1,577 | 1,682 | 1,712 | 1,669 | 1,609 | 1,665 | 1,698 | 1,739 | 1,268 |
| BIC       | 1,599 | 1,703 | 1,734 | 1,690 | 1,631 | 1,687 | 1,719 | 1,760 | 1,365 |
Conclusions

- Single most important driver of status changes is future profitability.

- **High future profitability** →
  - Fewer shutdowns & abandonments.
  - More startups.

- **Low future profitability** →
  - More shutdowns & abandonments.
  - Fewer startups.
Conclusions

- Strong evidence of real options effects.

- Regulatory uncertainty
  - Fewer shutdowns
  - Fewer startups

- Spark spread volatility
  - Fewer shutdowns & abandonments
  - More startups (but not for smallest plants)
Questions?
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 Stein-Erik.Fleten@iot.ntnu.no

Future plan

- Estimation of transition costs using structural estimation