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# 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 → more startups.

- Regulatory uncertainty
  - Reduces/delays status changes
    - More uncertainty → fewer shutdowns
    - More uncertainty → 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

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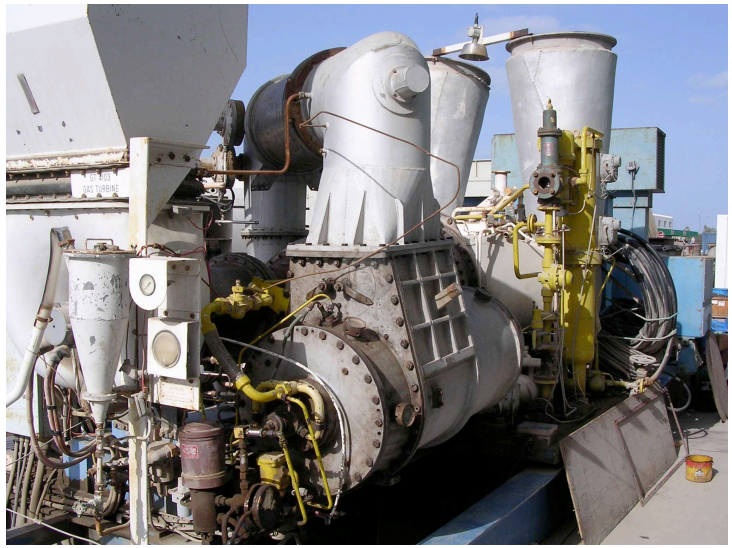
- Sample period 2001-2009
  - EIA 860 (data source) format changes in 2001
- Focus on peaking plants (CTs)
  - Natural gas and #2 oil
- Final sample:
  - 1,121 unique plants
  - 8,189 plant-year observations



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# Table I – Plant summary statistics

| | Age (years) | Size (MW) | Eff. (%) |
|---|---|---|---|
| NOBS | 1,121 | 1,121 | 1,121 |
| Mean | 18.6 | 43.1 | 24.7% |
| Stdev | 14.1 | 41 | 4.6% |
| Min | 0 | 0.4 | 5.4% |
| Max | 60 | 246 | 41.8% |

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- Status code
  - OP – operating
  - SB – on standby (mothballed/shutdown)
  - RE – retired

# Shutdown occurrences

| *from year* | *to year* | **OP** | **SB** | **Total** |
|---|---|---|---|---|
| 2001 | 2002 | 695 | 2 | 697 |
| 2002 | 2003 | 803 | 1 | 804 |
| 2003 | 2004 | 808 | 43 | 851 |
| 2004 | 2005 | 820 | 12 | 832 |
| 2005 | 2006 | 829 | 16 | 845 |
| 2006 | 2007 | 848 | 0 | 848 |
| 2007 | 2008 | 851 | 2 | 853 |
| 2008 | 2009 | 885 | 0 | 885 |
| | **Total** | 6,539 | 76 | 6,615 |

# Startup & abandonment

| *from year* | *to year* | **OP** | **SB** | **RE** | **Total** |
|---|---|---|---|---|---|
| 2001 | 2002 | 60 | 221 | 1 | 282 |
| 2002 | 2003 | 47 | 198 | 1 | 246 |
| 2003 | 2004 | 9 | 143 | 49 | 201 |
| 2004 | 2005 | 22 | 153 | 13 | 188 |
| 2005 | 2006 | 1 | 158 | 6 | 165 |
| 2006 | 2007 | 6 | 173 | 0 | 179 |
| 2007 | 2008 | 32 | 139 | 2 | 173 |
| 2008 | 2009 | 7 | 127 | 6 | 140 |
| | **Total** | 184 | 1,312 | 78 | 1,574 |

- Reserve margin
- $RM_{kt} = (C_{kt} - D_{kt})/D_{kt}$
  - $RM_{kt}$ – 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

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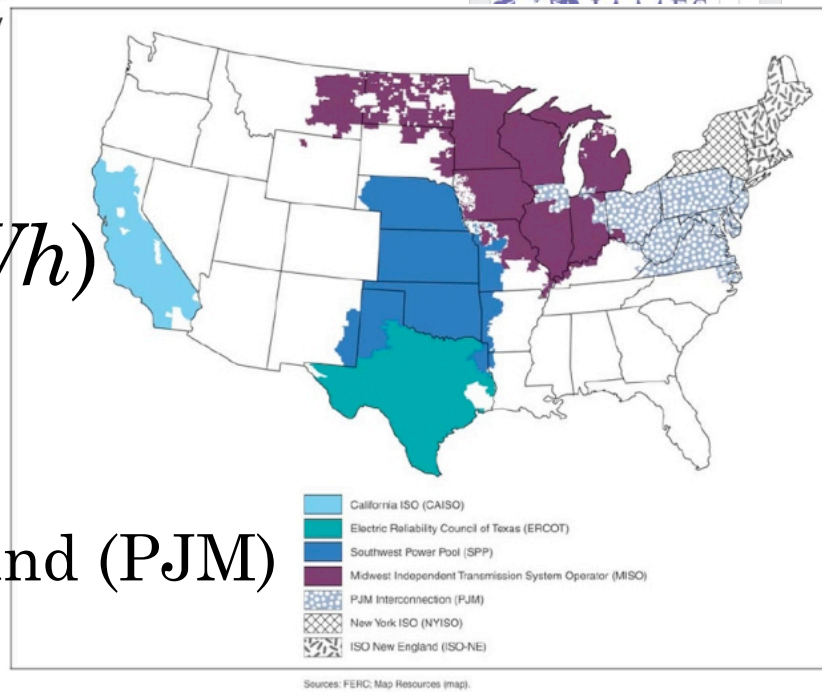
## ➢ Spark Spread ($/MWh)

$$SPRD_{ijkn} = PE_{kn} - HR_i\, PF_{jn} - VOM_i$$

- $PE_{k,n}$ = 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

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- 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

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## ➢ Spark spread volatility

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

- *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.

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# ➢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

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# ➢ Regulatory uncertainty indicator

- $REGUNCERT = 0$
  - When competition index = 1, 4, 5

- $REGUNCERT = 1$
  - When competition index = 2, 3

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# ➢ Regulatory uncertainty

- Likely to reduce the probability of ***any*** status change.

  - Fewer shutdowns
  - Fewer startups
  - Fewer abandonments

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- Shutdown Binary Logit Regression
  - Plant ***i*** (which is operating in year ***t***)
  - Fuel ***j***
  - Region ***k***

Define

$$I^{SB}_{i,t+1} \begin{cases} = 0 \text{ if plant } \boldsymbol{i} \text{ is operating in year } \boldsymbol{t+1} \\ = 1 \text{ if plant } \boldsymbol{i} \text{ is on standby in year } \boldsymbol{t+1} \end{cases}$$

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# Table VI – Shutdown estimation results

$$I_{i,t+1}^{SB} = \alpha + (\beta_1 * RM_{k,t+1}) + (\beta_2 * T10_t) + (\beta_3 * EFF_i) + (\beta_4 * SIZE_i) + (\beta_5 * TOTCAP_i)$$
$$+ (\beta_6 * SPRDSD_{ijk,t}) + (\beta_7 * REGUNCERT_t) + \varepsilon, \qquad (5)$$

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *RM* | 0.252*** | | | | | | | 0.235*** |
| *T10* | | -0.902*** | | | | | | 0.799** |
| *EFF* | | | -0.064** | | | | | -0.047* |
| *SIZE* | | | | -0.133** | | | | -0.052 |
| *TOTCAP* | | | | | -1.718*** | | | -1.416*** |
| *SPRDSD* | | | | | | -1.016*** | | -0.609* |
| *REGUNCERT* | | | | | | | -0.014*** | -0.012*** |
| pseudo-$R^2$ | 14.3% | 1.2% | 0.7% | 1.3% | 4.1% | 6.0% | 4.0% | 22.6% |
| Log-likelihood | -355.8 | -409.9 | -412.0 | -409.8 | -398.1 | -390.3 | -398.4 | -321.0 |
| AIC | 715.6 | 823.8 | 828.0 | 823.7 | 800.1 | 784.5 | 800.9 | 658.1 |
| BIC | 729.2 | 837.4 | 841.6 | 837.2 | 813.7 | 798.1 | 814.5 | 712.5 |

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- Startup & abandonment multinomial logit regression

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

Define

$$I^{OPRE}_{i,t+1} \begin{cases} 0 \text{ if plant } \boldsymbol{i} \text{ is operating in year } \boldsymbol{t+1} \\ 1 \text{ if plant } \boldsymbol{i} \text{ is on standby in year } \boldsymbol{t+1} \\ 2 \text{ if plant } \boldsymbol{i} \text{ is retired in year } \boldsymbol{t+1} \end{cases}$$

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# Table VIII – Startup & abandonment estimation

$$I_{i,t+1}^{OPRE} = \alpha + (\beta_1 * RM_{k,t+1}) + (\beta_2 * T10_t) + (\beta_3 * EFF_i) + (\beta_4 * SIZE_i) + (\beta_5 * TOTCAP_i)$$
$$+ (\beta_6 * SBTIME_{i,t}) + (\beta_7 * SPRDSD_{ijk,t}) + (\beta_8 * REGUNCERT_t) + \varepsilon, \qquad (6)$$

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Startup | *RM* | -0.835*** | | | | | | | | -0.757*** |
| | *T10* | | 7.764*** | | | | | | | -2.145 |
| | *EFF* | | | 0.542** | | | | | | 0.121 |
| | *SIZE* | | | | 1.117*** | | | | | 0.947*** |
| | *TOTCAP* | | | | | -4.064* | | | | -6.124** |
| | *SBTIME* | | | | | | -0.039*** | | | -0.035*** |
| | *SPRDSD* | | | | | | | 1.725*** | | 0.613 |
| | *REGUNCERT* | | | | | | | | -0.046 | -0.064*** |
| Abandon | *RM* | 1.057*** | | | | | | | | 0.242* |
| | *T10* | | -4.469*** | | | | | | | -1.237 |
| | *EFF* | | | -0.588*** | | | | | | -0.004 |
| | *SIZE* | | | | -2.664*** | | | | | -4.363*** |
| | *TOTCAP* | | | | | 10.965*** | | | | 12.322*** |
| | *SBTIME* | | | | | | 0.002 | | | 0.013*** |
| | *SPRDSD* | | | | | | | -3.229*** | | -1.367*** |
| | *REGUNCERT* | | | | | | | | -0.033** | 0.010 |
| | pseudo-$R^2$ | 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 |

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# ➢ 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.

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# ➢ 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)

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- Questions?
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- Future plan
  - Estimation of transition costs using structural estimation