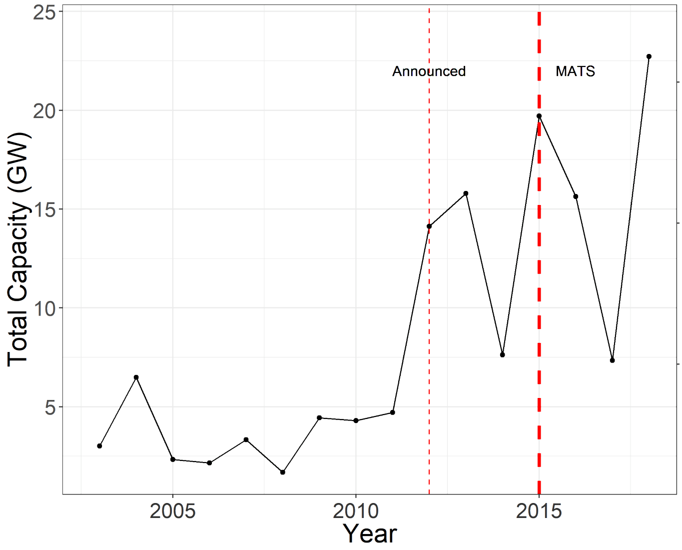
Effects of Market Conditions, Environmental Regulations and Regulatory Uncertainty on Investment and Exit

Wendan Zhang

University of Arizona, Department of Economics

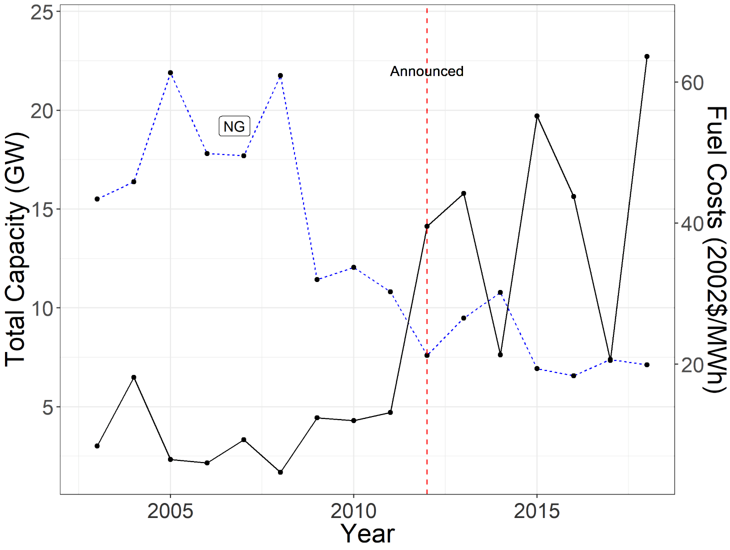
July 2020

Coal Power Plant Retirements & MATS



Mercury and Air Toxics Standards (MATS): Reduce mercury and other toxics by April 2015, with extension to April 2016.

Coal Power Plant Retirements & Fuel Prices



Recession & Natural Gas prices crashed. Advancement in the drilling technique that enables extracting oil and natural gas from shale rock.

Research Question & Approach

- Question: How do environmental regulations and natural gas prices affect coal power plant retirement decisions?
- Counterfactual: What would retirements have looked like if
  1. Absent the Mercury and Air Toxics Standards (MATS)
  2. Natural gas prices did not drop
- Approach
  - A Dispatch Model for estimating the coal generating units' variable profit from operating
  - A Single Agent Exit & Abatement Technology Investment Model to compare the impact of fuel prices versus the regulation MATS (work in progress, no results for this part)

Literature

1. Coal Power Plant Operation & Retirement
   - **Linn and McCormack (2019)**
   - Schiavo and Mendelsohn (2019)
   - Fell and Kaffine (2018)
   - Abito, Knittel, Metaxoglou, and Trindade (2018)
2. Dynamic Model
   - Rust (1987)
   - Muehlenbachs (2015)

Decision Making with Bellman Equation

For each unit i in year t, if it has not installed the required abatement technology, it can choose a_t among three options: Exit, Stay and Install. The value for choosing each option:

$$V(\boldsymbol{S_t}) = \max_{a_t} \begin{cases} \boldsymbol{\Phi} & +\boldsymbol{\varepsilon_{0t}} & & \text{Exit} \\ \boldsymbol{var\pi_t} & +\boldsymbol{\varepsilon_{1t}} & +\beta\mathbb{E}[V(S_{t+1})|\boldsymbol{S_t}, a_t] & \text{Stay} \\ & & & \end{cases}$$

Where

- $\boldsymbol{\Phi}$ is the scrap value for exit.
- $\boldsymbol{var\pi_t}$ is the variable profit from annual operation
- $\boldsymbol{\theta_I}$: installation cost θ_I for installing the technology in year t
- $\boldsymbol{\varepsilon_{at}}$: unobserved shocks associated with each choice a at time t, i.i.d. Extreme Value Type I Distribution
- $\beta = 0.9$: discount factor generally assumed
- $\boldsymbol{S_t}$: states that summarise the sufficient information for forming expectation $\mathbb{E}[V(S_{t+1})|\boldsymbol{S_t}, a_t]$

Decision Making with Bellman Equation

For each unit i in year t, if it has ~~not~~ installed the required abatement technology, it can choose a_t among three options: Exit, Stay ~~and Install~~. The value for choosing each option:

$$V(S_t) = \max_{a_t} \begin{cases} \mathbf{\Phi} & +\varepsilon_{0t} & & \text{Exit} \\ var\pi_t & +\varepsilon_{1t} & +\beta\mathbb{E}[V(S_{t+1})|S_t, a_t] & \text{Stay} \\ var\pi_t + \theta_I & +\varepsilon_{2t} & +\beta\mathbb{E}[V(S_{t+1})|S_t, a_t] & \text{Install} \end{cases}$$

Where

- $\mathbf{\Phi}$ is the scrap value for exit.
- $var\pi_t$ is the variable profit from annual operation
- θ_I: installation cost θ_I for installing the technology in year t
- ε_{at}: unobserved shocks associated with each choice a at time t, i.i.d. Extreme Value Type I Distribution
- $\beta = 0.9$: discount factor generally assumed
- S_t: states that summarise the sufficient information for forming expectation $\mathbb{E}[V(S_{t+1})|S_t, a_t]$

Estimation Approach

$$V(S_t) = \max_{a_t} \begin{cases} \boldsymbol{\Phi} & +\varepsilon_{0t} & & \text{Exit} \\ \boldsymbol{var\pi_t} & +\varepsilon_{1t} & +\beta\mathbb{E}[V(S_{t+1})|S_t, a_t] & \text{Stay} \\ \boldsymbol{var\pi_t} + \theta_I & +\varepsilon_{2t} & +\beta\mathbb{E}[V(S_{t+1})|S_t, a_t] & \text{Install} \end{cases}$$

1. Dispatch model to estimate the annual variable profit ($\boldsymbol{var\pi_t}$) for each unit
   - Estimate the marginal costs for each EGU and predict their annual supply
   - Calculate $\boldsymbol{var\pi_t}$ based on the supply prediction
   - Estimate $\boldsymbol{var\pi_t}$ as a function of some of the state variables (heat rate, capacity, demand and fuel costs ratio)
2. Single Agent Backward Induction for the structural parameters: scrap value ($\boldsymbol{\Phi}$) and installation costs ($\boldsymbol{\theta_I}$) (work in progress)

Estimation Approach

$$V(S_t) = \max_{a_t} \begin{cases} \mathbf{\Phi} & +\varepsilon_{0t} & & \text{Exit} \\ var\pi_t & +\varepsilon_{1t} & +\beta\mathbb{E}[V(S_{t+1})|S_t, a_t] & \text{Stay} \\ var\pi_t + \boldsymbol{\theta_I} & +\varepsilon_{2t} & +\beta\mathbb{E}[V(S_{t+1})|S_t, a_t] & \text{Install} \end{cases}$$

1. Dispatch model to estimate the annual variable profit ($var\pi_t$) for each unit
   - Estimate the marginal costs for each EGU and predict their annual supply
   - Calculate $var\pi_t$ based on the supply prediction
   - Estimate $var\pi_t$ as a function of some of the state variables (heat rate, capacity, demand and fuel costs ratio)
2. Single Agent Backward Induction for the structural parameters: scrap value ($\mathbf{\Phi}$) and installation costs (θ_I) (work in progress)

Variable Profit Prediction

$$var\pi_{it} = f(D_t, Cap_i, HR_i) + Cost_{st}\beta + \varepsilon_{it}$$

Table: Variable Profit Prediction

CoalCost			-4.7e+05***			-4.8e+05***	
			(8548.490)			(8596.830)	
NGCost			8279.017*			9010.786*	
			(4113.551)			(4113.900)	
Coal/NG ratio				-1.3e+08***			-1.3e+08***
				(2.9e+06)			(2.9e+06)
Demand	Y	Y	Y	Y	Y	Y	Y
Capacity		Y	Y	Y	Y	Y	Y
Heat Rate					Y	Y	Y
Observations	13,588	13,588	13,588	13,558	13,588	13,588	13,558
adj.R-squared	0.0154	0.542	0.6373	0.6097	0.5443	0.6392	0.6115

Next Steps

$$V(S_t) = \max_{a_t} \begin{cases} \mathbf{\Phi} & +\varepsilon_{0t} & & \text{Exit} \\ var\pi_t & +\varepsilon_{1t} & +\beta\mathbb{E}[V(S_{t+1})|S_t, a_t] & \text{Stay} \\ var\pi_t + \theta_I & +\varepsilon_{2t} & +\beta\mathbb{E}[V(S_{t+1})|S_t, a_t] & \text{Install} \end{cases}$$

- Estimate the scrap value and abatement technology installation costs in the dynamic model
- Counterfactual to compare the impact of fuel costs versus MATS

Thank You

Thank you for your time and suggestions.