Effects of vintage-differentiated environmental regulations - evidence from survival analysis of coal-fired power plants

Daniel Coysh (HM Treasury)

Joint work with Nick Johnstone, Tomasz Kozluk and Miguel Cardenas Rodriguez (OECD)

envecon, 3 March 2017
Increasing stringency of emission regulations has been accompanied by greater vintage differentiation (grandfathering/new source bias)

- "Existing" sources face more lenient standards than new sources

Vintage-differentiated regulations (VDRs) are a global phenomenon

- US: New Source Performance Standards
Background
The case for vintage-differentiated regulations

(i) **Static allocation efficiency**: cost effective for existing plants to face less stringent regulations, insofar as abatement less costly for new plants

(ii) **Intertemporal fairness and sunk costs**: equity grounds for not "changing the rules of the game" after a plant has already entered the market

(iii) **Expediency and political economy**: existing plants likely to have greater lobbying power than prospective entrants
→ VDR entails less political risk and more likely to pass
Motivation
Economic consequences of vintage-differentiated regulations

- Expected impact of VDR on entry, exit and capital turnover e.g. Stavins (2005)
  - New plants face higher regulatory compliance costs → depressed investment and entry
  - Generates rents for existing plants → reduced exit
  - Slower capital turnover and older average age of capital

- Higher share of older, more pollution-intensive units in plant portfolio (compared to uniform regulation)
  - Greater overall cost of achieving ambient standard or emission target
  - Indirect adverse implications for productivity

- Particularly relevant when sources subject to regulation have especially low rates of deterioration and technical obsolescence
Hypothesis

Vintage-differentiated regulations and plant exit

Hypothesis

Greater vintage differentiation of emission regulations reduces exit of existing plants.

- Existing plants:
  - Older plants benefiting from VDR, which face less strict emission regulations than new plants
  - Definition varies between countries and policies
Coal-fired electricity generation

Source: UDI’s World Electric Power Plant Database (WEPP), March 2016 release
Coal-fired electricity generation
Projected global trends in capacity (2014-2040)

Coal-fired capacity (GW)

Source: IEA World Energy Outlook 2015
Data

Key explanatory variables: regulatory stringency and differentiation

- Database developed in Johnstone et al. (2016)
- Panel data covering 31 mostly-OECD countries over the years 1962-2012

**Regulatory stringency**
- Inverse of the concentration limit (mg/m$^3$) mandated by a given standard
- 32 separate stringency variables, each one applicable to a certain combination of plant characteristics (vintage, size, coal type, pollutant)
- Use unweighted average

**Regulatory differentiation**
- Coefficient of variation (CV) between stringency for new and existing plants
Data
Regulatory stringency and differentiation (1962-2012)

Based on SO\textsubscript{x} regulations applicable to plant size 240MWth using hard coal. The stringency variable applies to new plants with these characteristics.

Data

UDI World Electric Power Plant Database

- Plant-level data on entry and exit
  - Construct unbalanced panel of 6,883 coal-fired plants that came online between 1962 and 2012
  - Match with regulatory variables based on country and year

- Controls
  - Plant-level
    - Capacity
    - Coal type (lignite dummy)
    - Cogeneration technology
    - Steam type
  - Firm-level
    - Electricity producer type
    - Single-plant firm dummy
  - Country-level
    - Share of coal in total electricity capacity
    - Market concentration (HHI)
    - Growth in coal (proxy for market profitability)
Methodology
Cox proportional hazards model

\[ h(t) = h_0(t) \exp(\beta_1 \text{str} + \beta_2 CV + \beta_3 CV \times \text{age\_dummy} + \beta_4 \text{'control'}) \]

- Hazard rate \( h(t) \)
- Baseline hazard \( h_0(t) \)
- Regulatory stringency \( \text{str} \)
- Regulatory differentiation \( CV \)
  - Interacted with age class dummy
- Controls
  - Plant, company and country level
  - Country and year fixed effects
## Results

Cox proportional hazards model

<table>
<thead>
<tr>
<th></th>
<th>(i) Country and year fixed effects</th>
<th>(ii) Year fixed effects only</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>exp (β)</td>
<td>β</td>
</tr>
<tr>
<td>Stringency</td>
<td>1.37</td>
<td>0.31**</td>
</tr>
<tr>
<td>CV</td>
<td>0.86</td>
<td>-0.16</td>
</tr>
<tr>
<td>CV * Units older than 30</td>
<td>0.57</td>
<td>-0.56***</td>
</tr>
<tr>
<td>Capacity (MW) y</td>
<td>0.37</td>
<td>-0.99***</td>
</tr>
<tr>
<td>Coal type lignite</td>
<td>1.23</td>
<td>0.21</td>
</tr>
<tr>
<td>Cogeneration technology</td>
<td>0.65</td>
<td>-0.43***</td>
</tr>
<tr>
<td>Steam type supercritical</td>
<td>1.69</td>
<td>0.53</td>
</tr>
</tbody>
</table>

**Electric production type**

<table>
<thead>
<tr>
<th></th>
<th>exp (β)</th>
<th>β</th>
<th>z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autoproducer</td>
<td>0.39</td>
<td>-0.94***</td>
<td>-4.18</td>
</tr>
<tr>
<td>Private power company</td>
<td>0.70</td>
<td>-0.35**</td>
<td>-2.00</td>
</tr>
<tr>
<td>Single-unit firm</td>
<td>3.39</td>
<td>1.22***</td>
<td>6.36</td>
</tr>
<tr>
<td>Share of coal in electricity (%)</td>
<td>1.21</td>
<td>0.19***</td>
<td>9.30</td>
</tr>
<tr>
<td>Growth in coal (%)</td>
<td>0.92</td>
<td>-0.08***</td>
<td>-5.25</td>
</tr>
<tr>
<td>HHI</td>
<td>0.98</td>
<td>-0.02</td>
<td>-0.70</td>
</tr>
</tbody>
</table>

**Year fixed effects**
yes

**Country fixed effects**
yes

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td># of failures</td>
<td>532</td>
<td>532</td>
</tr>
<tr>
<td># of observations</td>
<td>4785</td>
<td>4785</td>
</tr>
</tbody>
</table>

* p < 0.10, ** p < 0.05, *** p < 0.01 based on robust standard errors.

Notes: The dependent variable is years of operation. A hazard ratio exp (β) above one implies a higher probability of failure (increase in the hazard rate), as does a positive β-coefficient.
Results

Cox proportional hazards model

- Key findings
  (i) 1 SD increase in regulatory stringency increases hazard of exit by 37% (market-depressing effect of regulation)
  (ii) 1 SD increase in regulatory differentiation (CV) reduces hazard of exit by 51% for existing plants (impact on plant stock composition)

- Other significant determinants of plant exit
  - Greater capacity and cogeneration technology increase survival
  - Survival rates highest for autoproducers, followed by private power companies then utilities
  - Single-plant firms more likely to exit
  - Greater share of coal in total electricity capacity reduces survival rates

- Results robust across various specifications
Quantification exercise
Impact of differentiation on plant lifetime

Figure 8. Vintage differentiation and predicted lifetime of existing plants

CV percentile is based on the distribution of CV across countries within the sample in 2012.
Conclusions

- **Policy design**
  - Trade-off between benefits of VDR (static allocation efficiency; political economy) and unintended consequences (plant exit; age of capital stock)
  - Implications for:
    (i) Cost of achieving ambient standard or emission target
    (ii) Productive efficiency

- **Areas for further research**
  - Effects of slowed capital and plant turnover on environmental outcomes
  - Analysis of underlying motivations for introduction of VDRs (e.g. role of lobbying)
Thank you

Contact:
daniel.coysh@hm treasury.gsi.gov.uk