Efficiency and Productivity of U.S. Coal-Burning Power Plants

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Motivating Questions

- Are power plants efficient in minimizing cost?
  - Inefficiency is costly to power plants.
  - Inefficiency leads to higher electricity rates.

- Are power plants more productive over time?
  - What are the factors influencing productivity changes?
  - Helps inform technology transfer between power plants.
Definition of Terms

- **Efficiency**: generating the maximum amount of electricity given inputs.
  - Minimum amount of inputs to produce a given amount of electricity.
  - **Inputs**: labor, capital, and fuel.
  - **Output**: electricity.

- **Productivity**: rate of change in cost over time.
  - Cost increases at a decreasing rate as electricity production increases.
  - There are other factors too!
Why focus on cost and not production?

- **Electricity is demand-driven.**
  - Power plants cannot generate electricity to maximize profit.
  - Expensive to store electricity.

- **Objective:** given demand, power plants want to minimize costs.

- **Estimate a cost function.**
  - The determinants of cost are exogenous.
    - Input prices and output.
    - Inputs are predetermined in a production function.
Average overall efficiency is 85.3 percent.
- Average time invariant (persistent) efficiency is 93.9 percent.
- Average time varying efficiency is 90.7 percent.

Most power plants are more productive over time.
- Technical progress has the greatest impact on productivity.
Power plants are quite efficient in minimizing cost.
- 80 to 90 percent efficiency scores.
- **Popular recommendation**: increase electricity production.

Technical change.
- Most important component of productivity change.

Evidence of scale economies.
- Kleit and Terrell (2001) and Hiebert (2002).

Non-linear cost functions.
- No guarantee cost function properties will be satisfied.
What’s New?

- Separate overall efficiency into two components:
  - Time-varying efficiency.
  - Persistent efficiency.

- Flexible nature of the model.
  - True nature of cost determination is unknown.
    - Look at how the determinations of cost evolve over time.
  - Apply a method by Du et al. (2013)
    - Results are consistent with economic theory.

- Productivity decomposition for each power plant.
Methodology

- **Cost function:**

\[
\ln C_{it} = a(t) + \beta_1(t) \ln W_{1it} + \beta_2(t) \ln W_{2it} + \gamma_1(t) \ln Y_{1it} + \delta_1(t) \ln K_{1it} + \kappa_i + m_{it} + u_{it}
\]

where \(C_{it}\) - cost; \(w_{1it}\) & \(w_{2it}\) - energy & labor prices; \(Y_{it}\) - net electricity; \(K_{it}\) - capital; \(t\) - time trend; \(\kappa_i\) - persistent inefficiency; \(m_{it}\) - time-varying; inefficiency; \(u_{it}\) - error term.

- **Economic theory (constraints) – Du et al. (2013)**
  - Cost shares between zero and one.
  - Cost should not fall when electricity production rises.

- **Overall efficiency = persistent \times time-varying**

- **Productivity decomposition:** \(\Delta \ln C_{it} = \text{technical change} + \text{input price change} + \text{output change} + \text{capital change} + \text{inefficiency change} + \text{residual change}\)
## Data

<table>
<thead>
<tr>
<th>Variables</th>
<th>Source</th>
<th>Units of Measurement</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost</strong></td>
<td>FERC Form 1</td>
<td>millions U.S. $</td>
<td>131.65</td>
</tr>
<tr>
<td><strong>Output</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net Electricity</td>
<td>EIA’s 923 survey</td>
<td>gigawatt hours</td>
<td>6.39</td>
</tr>
<tr>
<td><strong>Input Prices</strong></td>
<td></td>
<td></td>
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<tr>
<td>Labor</td>
<td>Bureau of Labor Stats</td>
<td>U.S. Dollars</td>
<td>44,809</td>
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<tr>
<td>Energy</td>
<td>EIA’s 767 survey</td>
<td>U.S. Dollars</td>
<td>6.89</td>
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<tr>
<td><strong>Quasi-Fixed Input</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Capital</td>
<td>FERC’S Form 1</td>
<td>millions U.S. $</td>
<td>61.63</td>
</tr>
</tbody>
</table>
Results – Density Plots

Price for Fuel

Electricity Output

Capital

Returns to Scale
Results - Efficiency
Results – Efficiency Change

Index

Year


100 102 104 106 108
## Results - Productivity

<table>
<thead>
<tr>
<th></th>
<th>Technical change</th>
<th>Output change</th>
<th>Input Price change</th>
<th>Capital change</th>
<th>Inefficiency change</th>
<th>Residual change</th>
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<tbody>
<tr>
<td>Mean</td>
<td>-0.02</td>
<td>-0.02</td>
<td>0.01</td>
<td>0.00</td>
<td>-0.01</td>
<td>0.00</td>
</tr>
<tr>
<td>Median</td>
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<td>-0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>-0.02</td>
<td>0.00</td>
</tr>
</tbody>
</table>
Concluding Remarks

- Most power plants are quite efficient in minimizing cost.

- Scale economies for most power plants.

- There is evidence of technical progress.
  - The largest component of productivity change.

- Without negative shocks, expect improvement in efficiency.
  - Same expectation for productivity.

- Going forward: many states are debating deregulating electricity production and distribution.
  - Aim: deregulation = improved efficiency.