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

Jermaine Moulton

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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.

Preview of Results

- 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.

Relevant Literature

- Power plants are quite efficient in minimizing cost.
  - 80 to 90 percent efficiency scores.
  - **Popular recommendation**: increase electricity production.
    - Maloney (2001) and Hiebert (2002).
- Technical change.
  - Most important component of productivity change.
    - Nelson and Wohar (1983) and Martínez-Budría et al. (2003).
- 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:

$$lnC_{it} = \alpha(\boldsymbol{t}) + \beta_1(\boldsymbol{t})lnW_{1it} + \beta_2(\boldsymbol{t})lnW_{2it} + \gamma_1(\boldsymbol{t})lnY_{1it} + \delta_1(\boldsymbol{t})lnK_{1it} + \kappa_i + m_{it} + u_{it}$$

where C_{it}- cost; w_{1it} & w_{2it} - energy & labor prices; Y_{it} - net electricity; K_{it} - capital; t - time trend; κ_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.

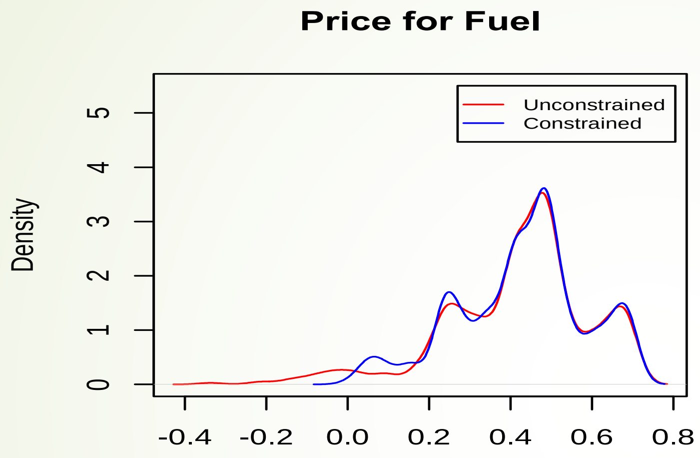
- Overall efficiency = persistent × time-varying

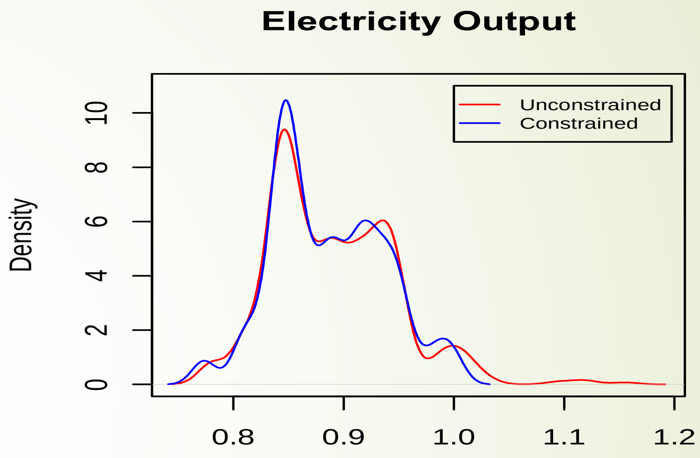
- Productivity decomposition: ΔlnC_{it} = technical change + input price change + output change + capital change + inefficiency change + residual change

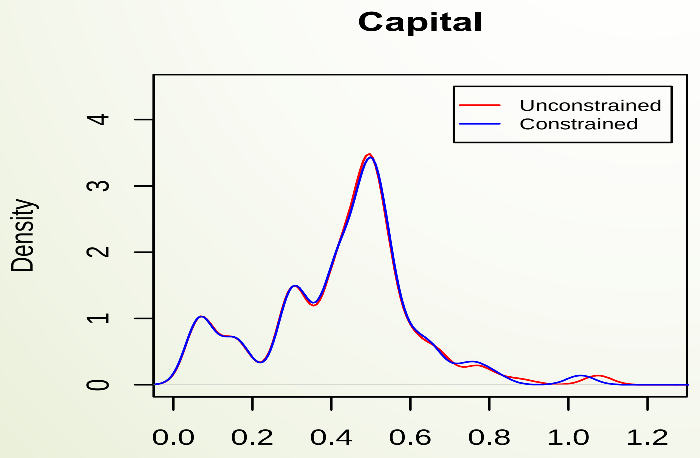
Data

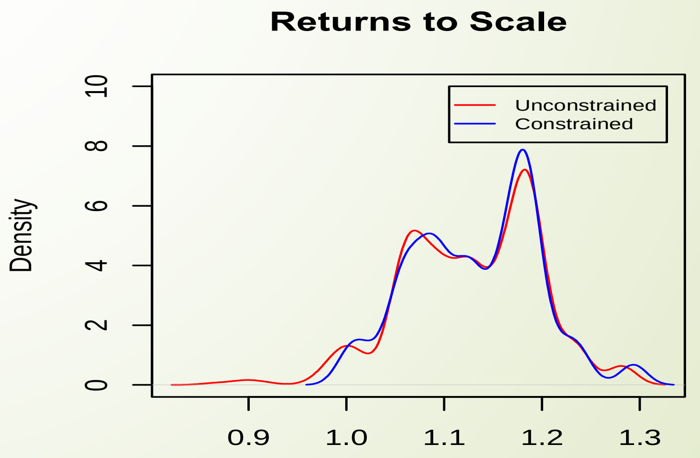
Variables	Source	Units of Measurement	Average
Cost	FERC Form 1	millions U.S. $	131.65
Output			
Net Electricity	EIA's 923 survey	gigawatt hours	6.39
Input Prices			
Labor	Bureau of Labor Stats	U.S. Dollars	44,809
Energy	EIA's 767 survey	U.S. Dollars	6.89
Quasi-Fixed Input			
Capital	FERC's Form 1	millions U.S. $	61.63

Results – Density Plots

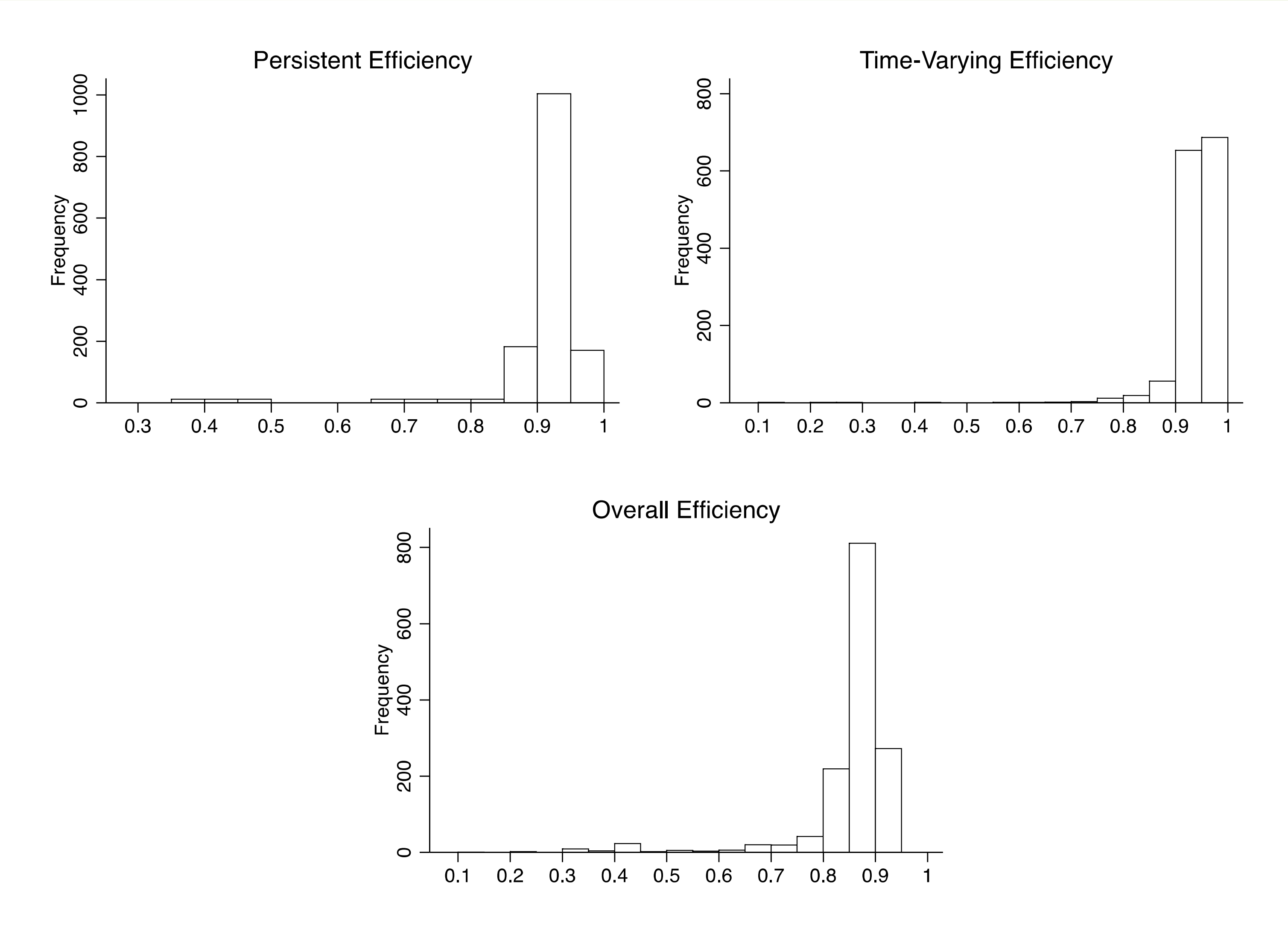




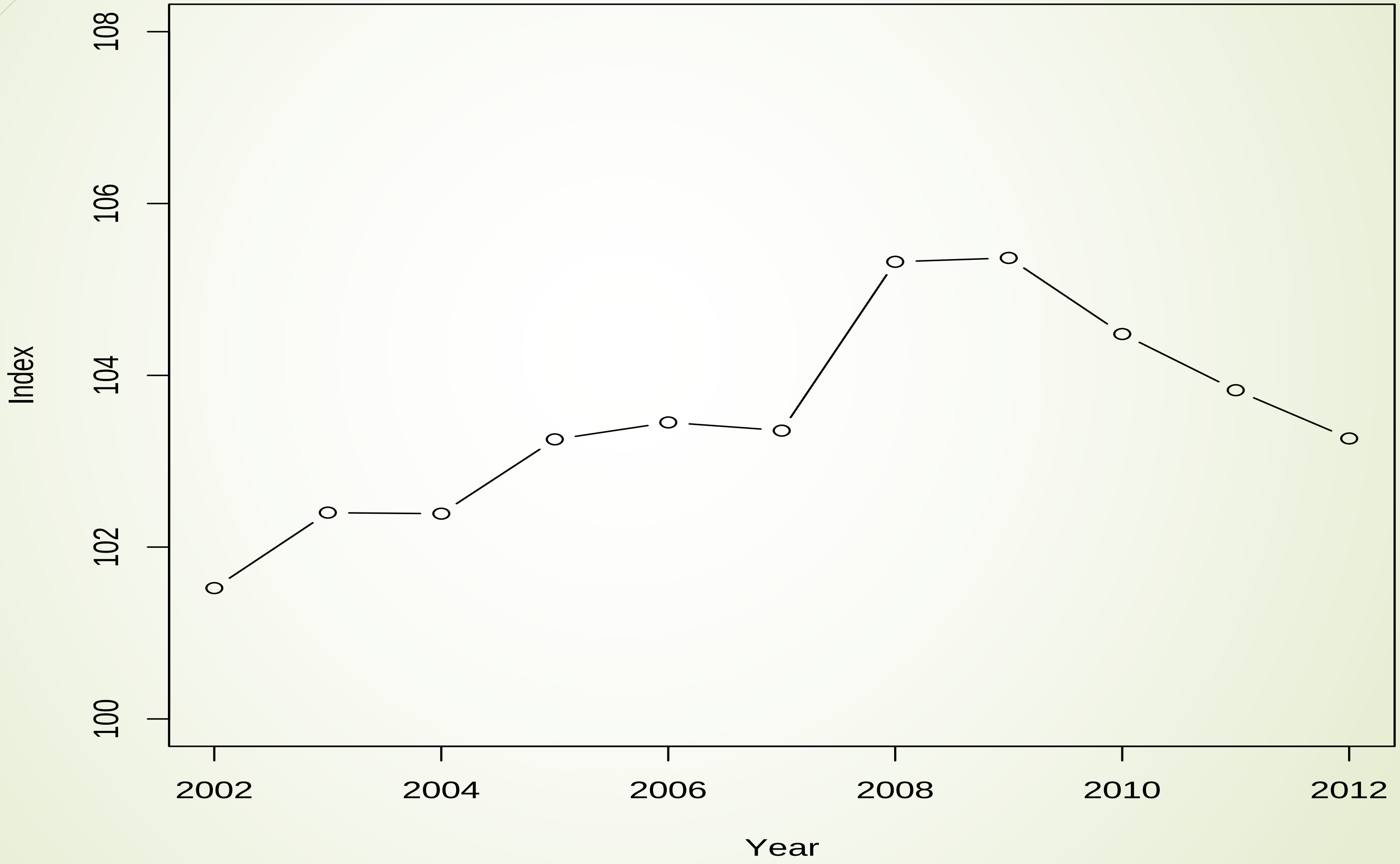




Results- Efficiency



Results – Efficiency Change



Results - Productivity

	Technical change	Output change	Input Price change	Capital change	Inefficiency change	Residual change
Mean	-0.02	-0.02	0.01	0.00	-0.01	0.00
Median	-0.04	-0.01	0.01	0.01	-0.02	0.00

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.