Examining the Productivity Growth of U.S. Electric Generation Plants Using the Biennial Malmquist Index Approach

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Introduction

- Electric generation practices in the U.S. have changed in recent decades due to state and federal energy policies and reductions in costs of some inputs.
- Improvements in technology like hydraulic fracturing has drastically reduced the cost of natural gas making it cheaper than coal.
- These changes in prices and government policies have led to changes in the production practices of U.S. electric generation plants.

Research Objectives

- To examine the productivity growth of electric generation plants in the U.S. (energy industry) using the biennial Malmquist index (BMI) under variable returns to scale.
- To decompose productivity growth to efficiency change and technical change to examine the sources of productivity.

Data

- This study used electric generation plant level data for the 2007-2014 period from Energy Information Administration (EIA).
- Thirty two inputs including capacity in a disaggregated level were used for the analysis. However, individual inputs like bituminous coal, lignite coal were combined to the coal group and so on to report in Table 1 (see Lynes (2015) for more details about individual inputs).

Table 1. Descriptive Statistics for Electric Generation Plants

Fuel Groups	Mean	Std. Dev.
Coal	4,052.22	19,366.71
Petroleum	785.50	8,271.52
Natural Gas	598.45	3,949.27
Nuclear	1,163.73	14,707.80
Renewables	798.62	3,502.48
Capacity (MW)	0.165	0.413
Net Generation (MWh)	199.97	1,431.95

Number of plants (N) = 2473

Note: All variables are in thousand and fuel groups are in million British Thermal Unit (MMBTU).

Research Methods

- The Data Envelopment Analysis (DEA) approach is used to estimate productivity growth.
- The biennial Malmquist index is calculated as the ratio of distance functions for the periods *t* and *t* + 1 following Pastor et al. (2011).

Biennial Malmquist index (BMI)

$$M_o^B(y^{t+1},x^{t+1},y^t,x^t) = \frac{D_o^B(y^{t+1},x^{t+1})}{D_o^B(y^t,x^t)}$$

where $M_0^B(.)$ and D_0^B are the BMI and the output distance function based on the biennial reference technology (*B*). The subscript "*o*" *denotes output orientation.* The value of BMI is greater (less) than 1 shows productivity progress (regress).

- The BMI is decomposed into two components: efficiency change and technical change.

- **Efficiency Change (EC)**

$$EC_v^B(.) = \frac{D_v^{t+1}(y^{t+1},x^{t+1})}{D_v^t(y^t,x^t)}$$

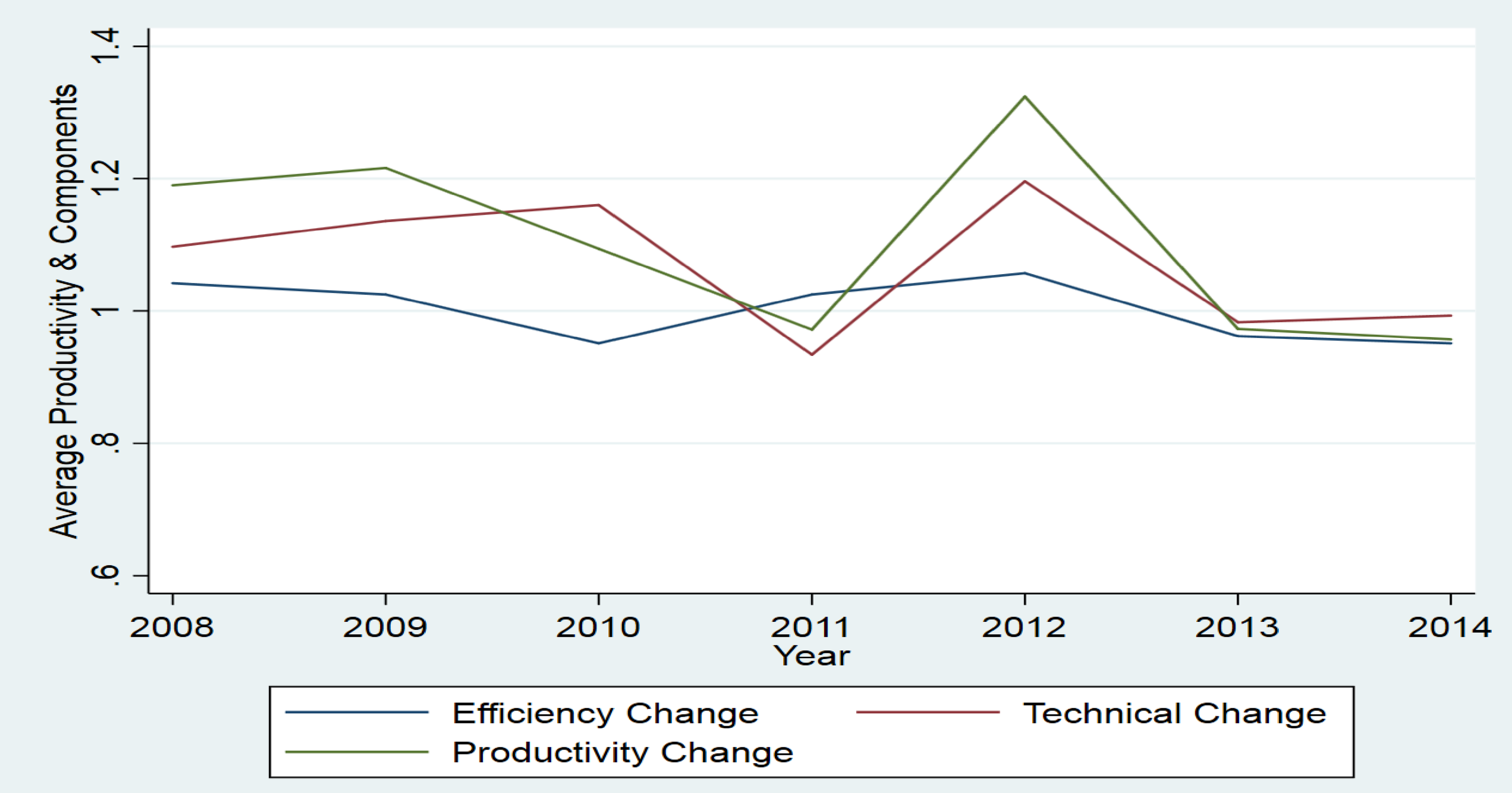
- A numerical value of efficiency change greater (less) than 1 indicates progress (regress).

- **Technical Change (TC)**

$$TC_v^B(.) = \frac{M_v^B}{EC_v^B} = \frac{D_v^B(y^{t+1},x^{t+1})}{D_v^B(y^t,x^t)} * \frac{D_v^t(y^t,x^t)}{D_v^t(y^{t+1},x^{t+1})}$$

- A numerical value of TC greater (less) than 1 indicates technical progress (regress) and the value of TC equals 1 indicates no technical change.
- The subscript *v* in BMI, EC, and EC represents variable to returns to scale. More details about the BMI optimization can be found in Pastor et al. (2011) and Pokharel (2016).

Figure 1. Average productivity and its components from 2007 to 2014



Result

Table 2. Productivity, Efficiency Change (EC) and Technical Change (TC) for the 2007-2014 Period.

Period	Productivity	EC	TC
2007-2008	1.19	1.042	1.097
	(0.213)	(0.132)	(0.121)
2008-2009	1.216	1.025	1.136
	(0.194)	(0.152)	(0.143)
2009-2010	1.094	0.951	1.197
	(0.163)	(0.114)	(0.124)
2010-2011	0.972	1.025	0.934
	(0.094)	(0.125)	(0.129)
2011-2012	1.324	1.057	1.196
	(0.081)	(0.143)	(0.145)
2012-2013	0.973	0.962	0.983
	(0.150)	(0.081)	(0.119)
2013-2014	0.957	0.951	0.993
	(0.131)	(0.093)	(0.141)

Note: standard deviations are in parentheses.

Conclusions

- Technical change was the major source of productivity growth rather than efficiency change.
- Electric generation plants can achieve higher productivity by adopting new technology and/or investing in technology.

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