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Productivity growth, technical change and economies of scale of Korean fossil-fuel generation companies, 2001–2012: A dual approach

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ABSTRACT

This paper examines total factor productivity (TFP) growth, technical change and economies of scale measure of Korean fossil-fuel power generation companies (GENCOs) between 2001 and 2012. For the empirical investigation, we estimated the cost function along with specification tests in order to find the most appropriate empirical model. Empirical results show TFP deterioration, technical regress, and economies of scale for the study period. The optimal size of the Korean GENCOs was also found, which is employed in developing policies regarding TFP growth and technical advance.

1. Introduction

The Korean electricity industry was supposed to undergo a serial reform after the 1997 Monetary Crisis. The reform in Korean electricity industry not only followed the global electricity restructuring trend during 1980s and 1990s but also attempted to overcome the 1997 Monetary Crisis in order to introduce competition to the a prior government-owned sectors such as electricity, telecommunication, steel production and so forth.

The reform aimed at increasing consumer's benefit by lowering the end-user price. The vertically integrated electricity industry, in which the *former* Korea Electric Power Corporation (KEPCO) had monopolized the generation, transmission, distribution and sales, was planned to be separated. In the initial plan of the reform, the generation function of the former KEPCO was taken over by six generation companies (GENCOs) and the new entrant to the generation market was allowed in order to make the market competitive. After the failure of selling to the public of the five fossil-fuel power GENCOs in 2002, these five GENCOs have been generating and wholesaling electricity as subsidiaries of KEPCO. Although they are subsidiaries, KEPCO cannot exercise its vote on the operations of GENCOs since the Ministry of Strategy and Finance holds the floor regarding them. The governance surrounding the GENCOs appears not to make the market competitive, as opposed to the planned objective.

Although the Korean electric wholesale market has attempted to transit to the de facto global standard, where price competition among GENCOs determines the wholesale price and generation quantity, it still shows an abnormal competition where price competition is limited and the government intervenes to the price determination (Nam, 2013). That is, an effective competition does not exist in the current Korean electric wholesale market, making it non-competitive. The long-term bilateral contract between generators and sellers is prohibited, whereas only trade through the hourly-based spot market is allowed through Korea Power Exchange (KPX). Even in the spot market, the bidders are only allowed to compete with each other not directly by the bidding but indirectly by the reveal of accounting costs. Every plant is obliged to report the marginal production cost to KPX, and the highest marginal production cost is chosen to determine the system marginal cost (SMP). The SMP is applied to determine the selling price of electricity for all the private GENCOs other than KEPCO's five subsidiary fossil-fuel GENCOs. For the KEPCO's five subsidiary fossil-fuel GENCOs, the augmented SMP, which is lower than the SMP, is applied to determine the selling price of electricity. The augment coefficient is also applied when setting the price, which is determined according to the plant type and the ownership and controlled by the government. It should be noted that the SMP has dramatically increased during the

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Table 1
Summary of previous studies on the electric sector.

Study	Units	Methods	Main results
Aghdam (2011)	Australian electric sector, 1969–2002	Malmquist index	TFP growth and technical progress
Arcos and de Toledo (2009)	Spanish electric sector, 1987–1997	Cost function	No evidence of ES; technical progress
Barros and Managi (2009)	Japanese steam power GENCOs, 1976–2003	Cost function	Technical regress
Christensen and Greene (1976)	US GENCOs, 1955–1970	Cost function	Sacrifice of ES
Fetz and Filippini (2010)	Swiss electric companies, 1997–2005	Cost function	Existence of ES
Fuller (1991)	US coal-fired GENCOs, 1965–1975	Cost function	Prevalence of ES
Färe et al. (1990)	Illinois electric utilities, 1976–1981	Malmquist index	TFP growth/deterioration, and technical progress/regress
Hisnanick and Kymn (1999)	US electric utilities, 1957–1987	Production function	Existence of ES
Nakano and Managi (2008)	Japanese electricity industry, 1978–2003	Malmquist index	TFP deterioration, and technical regress
Nemoto and Goto (2004)	Japanese electric sector, 1981–1998	Cost function	Existence of technical externality
Okunade (1993)	US steam-electric GENCOs, 1987	Cost function	Existence of ES

Note: ES represents economies of scale.

study period, which makes KEPCO stringent when purchasing and distributing electricity. The deficit of KEPCO, in turn, increased for the study period.

Because of the above-mentioned unique wholesale price system, the private GENCOs and the KEPCO's subsidiary GENCOs have been imperfectly competing with each other in generating and selling electricity with the same quality. For this reason, the KEPCO's subsidiary GENCOs do not have motivation to minimize the production cost by maximally utilizing base-load generation facilities, but they have increased peak-load generation to satisfy the national demands. The prevailing utilization of the peak-load generation facilities has increased not only the production cost of electricity but also the risk of electricity security. The blackout that occurred in 2011 was mainly caused by this prevailing utilization of the peak-load generation, where the high cost of peak-load generation has decreased the reserve margin in summer and winter seasons during the last decade.

This paper examines the generation activities of the five fossil-fuel GENCOs between 2001 and 2012, which correspond to the Korean electric reform period. Their activities were investigated by estimating the cost function from the perspective of total factor productivity (TFP) change and its decomposed factors, i.e., technical change and scale component. The TFP change is the change in the ratio of outputs to inputs; technical change is the cost reduction due to technical progress; and scale component is a measure of change in firm's size to secure the economically optimal size. For the empirical investigation, we employed econometric methods to investigate the cost function of the five fossil-fuel GENCOs using a firm-level data set. The empirical results show that i) TFP did not seem to increase during the study period, ii) technical regress occurred, iii) the GENCOs have increased their firm size, and iv) the optimal size has not yet been reached by any GENCOs.

The dual approach for examining GENCOs, which investigates the cost function, has long been regarded as a powerful and practical tool in that it reveals firm's internal process of production such as TFP change, economies-of-scale and technical change. Studies on the electric sector in the U.S. (Christensen and Greene, 1976; Fuller, 1991; Okunade, 1993), Japan (Nemoto and Goto, 2004), and Europe (Fetz and Filippini, 2010) reveal the prevalence of economies of scale by using the dual approach. Although their methodologies are able to be expanded to estimate TFP growth and technical change of GENCOs, the research scope appears to be limited in focusing only on measuring economies of scale.

The estimation of TFP growth and technical change can also be conducted using the primal approach, which is based on the production function or the Malmquist productivity index. For example, Aghdam (2011), Färe et al. (1990), and Nakano and Managi (2008) employ the Malmquist productivity index, and Hisnanick and Kymn (1999) use the production functional approach. The empirical results show the mixed growth in TFP and technical change across different countries and periods, i.e., TFP growth/deterioration and technical progress/regress were observed in these studies. The summary of previous studies is listed in Table 1.

As a similar measure to TFP growth, the concept of technical efficiency scores is employed in investigating thermoelectric or fossil-fuel power plants. Barros and Peypoch (2008) measure the technical efficiency scores of Portuguese thermoelectric power plants during 1996–2004 using a data envelopment analysis (DEA) technique, and rank the plants according to their relative efficiency scores. See and Coelli (2012) employ the Stochastic frontier analysis (SFA) framework to investigate the Malaysian thermal power plants during 1998–2005, and find that the technical efficiency has been significantly affected by various factors such as ownership, plant size and fuel type. Sueyoshi and Goto (2012) develop a new DEA framework that simultaneously considers i) the regulation change against the emissions of bad outputs and ii) the corporate strategy resulted from the regulation change. They employ the proposed methodology to U.S. fossil fuel power plants and argue that it is necessary to introduce new technology for environmental protection.

This study sets out to fill the gap that the dual approach lacks, by measuring TFP growth, technical change and scale component. By investigating these factors along with the economies of scale measure, practitioners are believed to make more sophisticated policies especially regarding the adjustment to optimal size, technical change and TFP growth of Korean GENCOs. A synchronous investigation into the TFP growth and its decomposed factors along with the optimal size makes it possible to provide multi-facet policies, for which little attempts have been devoted in previous studies. For example, although Aghdam (2011) analyzes the relationship between TFP growth and technical change, economies of scale (or, scale components) is not investigated. In spite of the fact that Arcos and de Toledo (2009) explore technical progress and the relationship among economies of scale, size and efficiency, the optimal size is not provided in their study. Huang et al. (2010) estimate the optimal size of Taiwanese electricity

Table 2
Descriptive statistics of variables used in this study.

Variable	Mean	Median	SD	Min	Max
Total cost (Mil. USD) 2889.1	3069.6	1257.7	724.2	5415.7	
Generation (TWh) 44.9	44.8	9.8	27.9	63.3	
Capital price (USD/kW)	81.1	80.5	19.9	42.2	131.7
Fuel price (USD/TOE)	203.8	198.4	82.4	60.9	407.3
Labor price (USD/FTE)	67,361.0	64,980.2	16,198.9	31,899.4	94,401.2

Note: All the costs and prices are transformed to year 2010 KRW by using the Korean producer's price index, where KRW is the currency of Korea. Then, KRW is converted to USD by using average annual exchange rates.