Energy Policy 83 (2015) 69–81

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

A CGE analysis for quantitative evaluation of electricity market changes

Won-Sik Hwang [a,*], Jeong-Dong Lee [b]

[a] Korea Institute for Industrial Economics & Trade, 370 Sicheong-daero, Sejong-si 339-007, Republic of Korea
[b] Technology Management, Economics and Policy Program Seoul National University, 1 Gwanak-ro, Gwanak-gu, Seoul 151-744, Republic of Korea

HIGHLIGHTS

- A novel approach is proposed for incorporating a top-down and bottom-up model.
- This study examines various counterfactual scenarios after Korean electricity industry reform.
- An improved regulatory system and policy measures are required before the reform

ARTICLE INFO

Article history:
Received 19 January 2015
Received in revised form
2 March 2015
Accepted 4 April 2015
Available online 11 April 2015

Keywords:
Computable general equilibrium
Market reform
Electricity industry

ABSTRACT

Risk and uncertainty entailed by electricity industry privatization impose a heavy burden on the political determination. In this sense, ex ante analyses are important in order to investigate the economic effects of privatization or liberalization in the electricity industry. For the purpose of fulfilling these quantitative analyses, a novel approach is developed, incorporating a top-down and bottom-up model that takes into account economic effects and technological constraints simultaneously. This study also examines various counterfactual scenarios after Korean electricity industry reform through the integrated framework. Simulation results imply that authorities should prepare an improved regulatory system and policy measures such as forward contracts for industry reform, in order to promote competition in the distribution sector as well as the generation sector.

1. Introduction

Liberalization and deregulation in the electricity market have been a global trend over the last three decades, but whether they result in lower electricity prices and production costs remains in doubt. Since the electric power industry is a central industry in the national energy sector, the Korean government has deliberated on appropriate ways of achieving a structural reform of the electricity industry. Nevertheless, the country lacks a clear, long-term vision for its energy market, and the electricity industry is stuck halfway between regulated vertical integration and market competition (Hwang and Lee, 2013). Risk and uncertainty entailed by market restructuring impose a heavy burden on political determination. This is why quantitative analyses should be conducted before irreversible market change is affected. This is the context for the present study.

The current electricity market system in Korea has not only caused many problems for consumers and producers but is also deemed to be unsustainable. The crucial policy issues in the electricity industry are to examine what kinds of vertical or horizontal divisions are proper in the electricity industry and what kind of market structure is optimal for the Korean economy. However, quantitative analyses of electricity market reform in Korea are not enough.

Although most studies on the electricity industry reforms have attempted to examine this issue through case studies or econometric approaches from the perspective of partial equilibrium (Zhang et al., 2008), some previous studies on electricity industry reform depended on top-down (TD) models, especially CGE models, taking into account economic interaction among energy substitutes. They were based on simple assumptions that electricity market reforms would bring more efficiency in production and reduce markup prices attributed to a monopolistic market structure. Because of these optimistic assumptions, the evaluation of the reform suggests positive effects on the national economy. For example, Akkemik and Oguz (2011) assumed that liberalization would remove X-inefficiency, which was set to 15 percent, as well as markups over marginal cost, which was set to 10 percent for capital earnings. Their simulation results indicated that the reform would increase household utility by 1.08 percent of GDP and decrease energy composite prices by 13.5 percent for

* Corresponding author.
E-mail addresses: yel0sik@snu.ac.kr (W.-S. Hwang), leejd@snu.ac.kr (J.-D. Lee).

http://dx.doi.org/10.1016/j.enpol.2015.04.006
0301-4215/

households.

On the other hand, bottom-up (BU) models have made assumptions on fuel and electricity costs, energy consumption, and lifetimes of technologies currently in use and their alternatives, as well as potential rates and limits of alternative technology penetration. In general, BU modelers recognize energy–economy interactions as not only changing but also changeable. However, they lack a comprehensive perspective of the energy market and a solution to market clearing problems, and this may lead to misjudgment of the rate or scope of change. As Wilson and Swisher (1993) argued, BU analysts tend to be overly optimistic in areas that lie furthest from their expertise (such as estimating transaction costs) and overly pessimistic in areas where they know the most (such as anticipating future technological developments).

This study makes two large contributions in the methodological and political aspects of the subject. First, in terms of methodologies, a novel approach is suggested for analyzing the Korean electricity market. Based on decomposition approaches with TD and BU models (Böhringer and Rutherford, 2009; Lanz and Rausch, 2011), distinctive iterative processes are used that are modified elaborately to investigate the economic effects from electricity market changes. Since price elasticity of demand for electricity generally tends to be very low, convergence may not be guaranteed during an iterative process between TD and BU models, when compared to other goods with high price elasticity. Provided that electricity prices or price conditions are determined in the BU model and transferred to the TD model, solutions from the interaction between the two models are more likely to converge. Moreover, if electricity prices are set in the supply side, the strategic behaviors of suppliers can be implemented more easily in the BU model. Electricity prices increase because of the strategic behaviors of suppliers and they are subsequently reflected into the TD model by adjusting scarcity rents on the capacities of power generation technology. In other words, scarcity rents that differ between marginal costs and electricity prices in conventional hybrid models are used to represent monopoly or oligopoly rents.

Second, this study examines various counterfactual scenarios in the Korean electricity industry and analyzes macroeconomic impacts after electricity market reform. There have been few computable general equilibrium (CGE) studies that assessed the quantitative effects of Korea's electricity industry privatization and market changes. In this study, quantitative evaluations were conducted for ex ante assessment of changed price levels in the electricity market after privatization and to investigate the market power of dominant companies and their ability to influence price determination through strategic behaviors in the privatized market.

The remainder of this paper is organized as follows. Section 2 explains details of the TD and BU model and how the two models are integrated. In Section 3, after a converging algorithm for the iterative process is explained, empirical results from the integrated model are provided, assuming various market conditions. Finally, Section 4 offers conclusions and suggests policy implications for future Korean electricity market reform.

2. Methods

2.1. Korean small economy CGE model

In this study, sectors are aggregated according to 403 basic classifications in the 2009 input–output (IO) table published by the Bank of Korea. The mapping between sectors in the social accounting matrix (SAM) and the 403 classifications is described in Table 1. The whole industry is divided into 14 sectors, including seven energy-specific sectors. The energy sectors consist of four energy-source sectors (COAL, ROIL, OIL, LNG) and three electricity-related sectors, which are comprised of electric power generation (EGEN), electricity transmission (ETRN), and electricity distribution (EDST). The 403 basic classifications in the Korean IO table separate the electricity industry into four sectors: 'hydroelectric power generation' (298th), 'fire power generation' (299th), 'nuclear power generation' (300th), and 'other generation' (301th). They are aggregated into a generation sector (EGEN) in the CGE model, while the separated data are used to assign the production cost of each type of generator in the BU model.

Table 1
List of sectors in the SAM.

Sectors	Abbreviations	403 basic classifications
Agriculture, forestry, fishing, and mining	AGRI	001–029, 034–044
Chemicals, drugs, and medicines	CHEM	142–171
General machinery and transportation equipment	MACH	220–239, 274–287
Electronic and electrical equipment, precision instruments	ELEQ	240–273
Textile, metal, and other manufactured products	OTHR	045–130, 172–219, 288–297
Aggregation of service industries	SERV	303–326, 341–403
Transportation	TRAN	327–340
Coal and coal products	COAL[a]	030, 031, 131, 132
Refined petroleum products	ROIL[a]	133–141
Crude petroleum	OIL[a]	032
Natural gas	LNG[a]	033, 302
Electric power generation	EGEN[a,b]	298, 299, 300, 301
Electricity transmission	ETRN[a,b]	–
Electricity distribution	EDST[a,b]	–

[a] Energy sectors.
[b] Electricity industry sectors.

There are no corresponding sectors in the IO table for power transmission and distribution whose economic transactions are contained in the generation sectors. In order to reconstitute electricity transmission and distribution sectors, other financial data[1] were collected. Disaggregating value added of the power transmission and distribution sector from the aggregated generation sector requires two steps. The first step is separating total value added for power transmission and distribution from the generation sector. Using data in balance sheets, capital rents for the transmission and distribution sector are divided through the ratio of tangible assets between Korea Electric Power Corporation (KEPCO) and six subsidiary generation companies (GENCOs). This is reasonable, since the six GENCOs account for most electricity power generation in Korea and KEPCO monopolistically operates the power transmission and distribution sector. Labor costs in value added are divided in proportion to wages in KEPCO's and the six GENCOs' income statements.

The second step is to allocate total value added into the power transmission and distribution sector separately. In Fig. 1, 'C' and 'D' represent value added in the transmission sector, 'E' and 'F' in the distribution sector. Many studies[2] use total length of transmission lines and total length of distribution lines as proxies for physical capital input. In this context, value added on capital and labor is allocated into the two sectors proportionally to their total line lengths, as obtained from *Statistics of Electricity Power in Korea*

[1] The main data sources on the Korean electricity industry are *Statistics of Electric Power in Korea* (KEPCO, 2010) and Electric Power Statistics Information System (EPSIS; https://epsis.kpx.or.kr/).

[2] More specifically, other studies took into account additional variables with physical line length such as capacities of the distribution transformer (Goto and Tsutsui, 2008) or separated lines as high and low voltage power lines (Hjalmarsson and Veiderpass, 1992)