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General Equilibrium Analysis of Electricity Market Liberalization in Singapore: A Comparative Study

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Abstract. *The liberalization in electricity market in Singapore has being undertaken for more than 15 years. This paper evaluates the influence of competition policies by computable general equilibrium (CGE) model. Instead of the direct measurement of the impact of competition policy, the benefit of liberalization is reflected by the simulation of a hypothetical regulatory condition. Comparing to the regulatory scenario, simulation result implies the current liberalization raises GDP and exchange rate significantly, but also leaves the tradeoff between higher national income and lower consumer welfare to government. If such choice of economic policy is necessary for political demand, a formal legal framework is required to enforce the restoration of the economy from regulatory restrictions.*

Keywords: electricity market; general equilibrium; liberalization; Singapore.

JEL Codes: C68, L43, L51, P51.
REL Code: 17E.

1. Introduction

In last decades, the global electricity market has experienced successive reforms of regulation. These reforms aimed to relax the public controls and alleviate political distortion in such industry previously dominated by state monopolies. Since 1995, Singapore also pushed the electricity market liberalization by issuing several legal and competition policies.

Electricity industry is generally regarded as natural monopoly because of its strong property of economies of scale, thus should be regulated. However, regulation also brings inefficiency in cost control. For Singapore, electricity is an important intermediate input in economy, and the demand of electricity is rapidly growing as shown in Table 1.

Table 1

Electricity Generation and Sales

Year	Generation (GWh)	Sales (GWh)
1995	22,057.4	20,239.6
2000	31,665.0	29,133.1
2001	33,088.5	29,596.5
2002	34,664.5	31,089.3
2003	35,330.6	31,985.7
2004	36,809.6	33,171.2
2005	38,212.7	34,761.3
2006	39,442.0	35,921.8
2007	41,134.2	37,420.3
2008	41,716.8	37,940.3
2009	41,800.6	37,974.2
2010	45,367.5	41,199.8

Source: Yearbook of Statistics Singapore 2006, Yearbook of Statistics Singapore 2011.

The average annual growth rates of electricity generation and sales through 1995-2010 are both 4.9%, which results from the concentration of large energy users as foreign direct investment. Therefore the liberalization in electricity market just responds to the large energy consumption and maintains its attractiveness for foreign capital as Singapore development strategy.

In this paper, I evaluate the impact of liberalization of electricity market in Singapore by comparative method from general equilibrium perspective. The computable general equilibrium (CGE) model combined with a hypothetical scenario gives the comparison of macroeconomy of liberalization and price regulation.

2. Review of electricity market liberalization

The liberalization of electricity market in Singapore can be traced back to 1995, when Public Utility Board (PUB) was the sole energy provider of water, electricity and gas. And then government concluded to transfer the electricity and

gas business to Singapore Power Ltd. (SP), and remain the regulatory function of PUB in energy sector. Although SP is corporate entity, it is still state-owned, and owning the generation, transmission and retail segments of the industry. In 1998, the government implemented a wholesale electricity market Singapore Electricity Pool (SEP), to facilitate electricity trading between generators and retailers, as a prelude to opening the retail segment to competition.

In 2000, the government separated the natural monopoly segments, i.e. transmission and distribution, from competitive segments, i.e. generation and retail. Then the electricity supply moved to a more competitive structure under legal framework in 2001: government issued Public Utilities Act that remove the regulatory function of PUB and transfer the responsibility of PUB to the Ministry of the Environment and Water Resources from the Ministry of Trade and Industry; established a new regulatory agent, the Energy Market Authority (EMA); passed the Electricity Act and Gas Act, so the electricity and piped gas industries were enforced as competitive markets. Meanwhile, the Energy Market Company Pvt. Ltd. (EMC) was set up as a joint venture between EMA and M-co (the Marketplace Company) Pte Ltd as the wholesale market operator.

The liberalization came into a new period in 2003, when the National Electricity Market of Singapore (NEMS) began to operate. With the new regulatory framework, EMA grouped consumers into contestable and non-contestable categories. Consumers are deemed "contestable" if they have maximum power requirements exceeding 2MW, then they could purchase electricity from either the retailers, the wholesale market via the Market Support Services Licensee (MSSL) or trading directly in the market. Non-contestable customers can only buy from SP Services, which is responsible for providing electricity supply to non-contestable customers as well as support services.

The timeline for contestability is divided into three phrases. In Phase 1, the number of consumers with an average monthly consumption exceeding 20 MWh was 250 on January 2003, and up to the end of 2003, 5,000 contestable customers had been approved; in Phase 2, another 5,000 contestable consumers with an average monthly consumption of 5 MWh or more had been approved in six months; the remaining 1.1 million consumers with average monthly consumption of less than 10 MWh to be contestable in Phase 3 by the end of 2004.

3. Computable general equilibrium model

To explore the impact of policy change on macroeconomic performance, a computable general equilibrium (CGE) model is widely used instrument. Here I also apply this model in the liberalization of electricity market of Singapore. By observing the Input-Output Tables of Singapore for 2005, which are the latest I-O tables published for Singapore, I categorize 153 social sectors of Singapore to 11 sectors: (1) Agriculture, (2) Manufacturing,

(3) Construction, (4) Commerce, (5) Transport & Information Communication, (6) Financial Services, (7) Business Services, (8) Electricity, (9) Water, (10) Gas, and (11) Other Services, where Electricity, Water, and Gas sectors can be disaggregated from Utility sector according to the absorption table in the Input-Output Tables of Singapore for 2005.

In this model, I construct a fully regulated electricity market by imposing marginal cost pricing to firms. By this hypothetical constraint, I can compare the macroeconomic variables under regulation to the current liberalization, which has been derived as the benchmark outcome, and then measure the benefits of liberalization inversely.

3.1. Production

For the production side, I follow the conventional constant returns to scale assumption in CGE model and separate production to two stages. In the first stage, I aggregate labor and capital through Cobbe-Douglas production function:

$$VA_i = \omega_i \times A_i^{\alpha_i} \times K_i^{1-\alpha_i} \tag{1}$$

where ω_i is the efficiency parameter, a_i is the share of labor in output, and i denotes different production sectors. And in the second stage, I integrate the value-added and intermediate input in Leontief production function:

$$Q_i = min\left(\frac{VA_i}{\alpha_{VAi}}, \frac{q_{1i}}{\alpha_{1i}}, ..., \frac{q_{ni}}{\alpha_{ni}}\right) \tag{2}$$

where Q_i is the quantity of output, VAi and q_{ni} are the quantity of value-added and intermediate input respectively, and α_{VAi} and α_{ni} refer to the fixed proportion of each factor of production utilized.

Every sector is assumed to be constant returns to scale except electricity, since electricity industry has a strong property of economies of scale, which indicates decreasing long-run average cost, and corresponds to increasing returns to scale in terms of output (Hosoe, 2006), so I separate the electricity sector from these 11 sectors and subscript it by e. For this reason, the CGE model allows electricity sector to earn markup beyond marginal cost, and the real rate of return in electricity sector can be descripted by markup rate μ in terms of capital:

$$r_{Ke} \times K_e = (1+\mu)\bar{r}_{Ke} \times K_e \tag{3}$$

where r_{Ke} is the marginal product of capital, and bar denotes the situation of perfect competition.

3.2. Demand

The model assumes a representative household, and the utility function of the consumption of this representative household is a Cobb–Douglas function of individual consumption goods:

$$U = \prod C_i^{\alpha_i} \tag{4}$$

where C_i is the consumption level of good i and α_i is the share of good i in total household consumption expenditure.

The representative household contributes labor and capital to production, and earns factor income as household income, such as wage and dividend less income tax. Addition to factor income, household receives the transfer payment from government as part of household income.

3.3. Trade

To describe trade, I assume the trade of Singapore does not affect world price, in other words, to assume constant terms of trade. With this assumption, the trade equation is specified as the constant elasticity of transformation (CET) function. In this form, domestic sales and exports of goods make up the gross output. On the other hand, goods sold domestically and imported from abroad should meet the demand of domestic firms and household, and the combination of the domestic goods and imports follows the constant elasticity of substitution (CES) function with Armington model, which assumes imperfect substitution between home and foreign goods in consumption.

3.4. Government

The aim of liberalization is to remove the intervention of political power in market, thus here I assume the government only considers the redistribution of income. The government collects tax from firms (corporate tax), households (income tax), and imports (import tariff), and redistribute the revenue in the form of expenditure and transfer payment.

3.5. Macroeconomic balances

The CGE model requires three macroeconomic balances: the government balance, the current account balance, and the savings-investment balance to reach macroeconomic closure. The government balance imposes equality between government revenue and the sum of government expenditures and savings:

$$Y_G = E_G + S_G \tag{5}$$

where government savings S_G is assumed to be fixed in practice of CGE modeling.

The current account balance imposes equality between the spending of a country and the earning of foreign exchange:

$$\sum pwm_c \times QM_c + \sum trnsfr_O = \sum pwe_c \times QE_c + \sum trnsfr_I + S_F \tag{6}$$

where pwm_c and pwe_c are the import price and export of commodity c respectively; and $trnsfr_o$ and $trnsfr_I$ are the transfers out of country and transfers to country respectively; and S_F refers to foreign savings. In this model, foreign savings is exogenous and fixed, and the exchange rate is flexible.

The savings–investment balance incorporates total investment and total savings:

$$\sum I_{Pri} + \sum I_{Pui} = S_I + S_G + S_F \quad (7)$$

where I_{Pri} and I_{Pui} are the private and public investment of good i respectively, and S_I is private savings, including savings of firms and households.

3.6. Data base and calibration

A social accounting matrix (SAM) is needed for solving CGE model. Based on the research purpose and data availability, follow the fashion of Akkemik (2009), I prepare the SAM for Singapore and set 2005 as the base year by the Input-Output Tables of Singapore for 2005. The SAM consists of 11 commodity and activity sectors as organized at the beginning of Section 3, four institutions (enterprises, households, government, and the rest of the world), and two production factors (labor and capital).

The data for SAM is mainly obtained from I-O Tables of Singapore for 2005, but there are still few parts come from various sources such as the yearbook of statistics (labor income) and government budget (transfers among institutions), so the original SAM was unbalanced. The unbalanced original SAM was balanced by using the cross-entropy method, i.e. estimate the domestic sales and transfers to minimize cross-entropy distance. The aggregate SAM is shown in Table 2:

Table 2

Aggregate SAM for Singapore 2005 (Unit: Billion Singapore Dollars)

	ACT	COM	FAC	ENT	HOU	GOV	CAP	ROW	Total
ACT		61.7						298.9	360.6
COM	161.3				83.8	21.9	41.7		308.7
FAC	195.8							13.9	209.7
ENT			111.9			1		-23.4	89.5
HOU			83.9	11.3		0.6			95.8
GOV	3.5	9.5		7.1	4			17.2	41.3
CAP				72.9	8	18		-47.6	51.3
ROW		237.5	13.9	-1.8		-0.2	9.6		259
Total	360.6	308.7	209.7	89.5	95.8	41.3	51.3	259	

Notes: ACT: activities account; COM: commodities account; FAC: factors account; ENT: enterprises account; HOU: households account; GOV: government account; CAP: capital (saving-investment) account; ROW: rest of the world account.

Source: Singapore Input-Output tables 2005, Yearbook of Statistics Singapore 2006, Government Budget 2006.

4. Regulatory policy simulation

Generally speaking, the counterpart of liberalization is regulation, so I shall assume a hypothetical scenario of regulation before macroeconomic simulation, for comparison between the current liberalizing and hypothetical regulated environment. This scenario can be realized by supposing government implements a price regulation in electricity market, for example, removes the markup of electricity pricing. This seems an unrealistic assumption since it simultaneously assumes symmetric information between firms and government and cost-free subsidy to sustain firms, but it still provides the outcome of "artificial" marginal cost pricing comparing to the perfect competition. The markup rate in the electricity market in Singapore in 2005 has been calculated by Chang (2007), which is 0.188.

Now make the model allow the endogenously determined intermediate input, production supply and demand, and the international trade. The base situation of the CGE solution can be regarded as the benchmark, which represents the current liberalizing process, and the result of the simulation of regulatory scenario provides the variation of key variables in regulation relative to liberalization. The result of simulation is shown in Table 3:

Table 3

Macroeconomic Result

Variables	Percentage change relative to benchmark
Electricity price	-18.8
Electricity consumption	0.13
GDP	-1.69
Equivalent variation/GDP	0.18
Private consumption	0.52
Government consumption	0.04
Exchange rate	-0.29

According to the simulation result, the regulation may increase the utility of households by 0.18 percent of GDP, measured by Hicksian equivalent variations method. This welfare improvement is attributed to the decreased price of electricity and other goods that use electricity as intermediate input. The GDP will considerably fall by 1.69 percent under regulation, which is associated with the significant fall of exchange rate that greatly appreciates Singapore dollars relative to foreign currency and reduces net import.

5. Conclusion

This paper gives the quantitative comparison between current liberalizing and fully regulatory economy by CGE model. The current liberalization in electricity market in Singapore ensures the rapid development of economy by balancing the benefits among economic sectors. According to the research of Chang (2007), the markup rate of electricity market is decreasing from 2003, thus we may expect the liberalization and competition policies in electricity and complement markets would generate more incentives to move to a more competitive economic environment.

This paper also provides suggestions on policy implementation, either for the liberalization side or the regulation side. The intention of liberalization is to gain the efficiency, reduce price and user cost, lower entry and exit barriers, and improve social welfare; and the last one is also the starting point of regulation. However, the restrict regulation does reduce the electricity cost of institutions, and improves the consumer welfare to some extent, but would cause a deterioration of national current account because of the appreciation of domestic currency. Although such regulatory policy is needed in certain times for political and economic stabilization, a formal legal framework is required, to enforce the conditions of policy to restore the economy from regulatory restrictions.

References

Akkemik, K., Oguz, F., "Regulation, Efficiency and Equilibrium: A General Equilibrium Analysis of Liberalization in the Turkish Electricity Market", *Energy*, 36(5), 2011, pp. 3282-3292

Akkemik, Kucuk Ali (2009). *Industrial Development in East Asia: A Comparative Look at Japan*, Korea, Taiwan, and Singapore, World Scientific

Brennan, T., Palmer, K., Martinez, S., "Implementing Electricity Restructuring}, *Environmental and Resource Economics*, 22(1), 2002, pp. 99–132

Chang, Y., "The New Electricity Market of Singapore: Regulatory Framework, Market Power and Competition", *Energy Policy*, 35(1), 2007, pp. 403-412

Chang, Y., Tay, T., "Price Responsiveness in the New Electricity Market: A Singapore Experience. Proceedings of the 2004 IEEE International Conference on Electric Utility Deregulation", *Restructuring and Power Technologies*, 2004, pp. 44-48

Chang, Y., Tay, T., "Efficiency and Deregulation of the Electricity Market in Singapore", *Energy Policy*, 34(16), 2006, pp. 2498-2508

Lofgren, H., Harris, R., Robinson, S. (2002). *A Standard Computable General Equilibrium (CGE) Model in GAMS*, International Food Policy Research Institute

Hosoe, N., "The Deregulation of Japan's Electricity Industry. Japan and the World Economy", 18(2), 2006, pp. 230-246

Robinson, S., Cattaneo, A., El-Said, M., "Estimating A Social Accounting Matrix Using Cross Entropy Methods", *IFPRI-TMD Discussion Paper Series*, Paper No. 33, 1998