A Spatial Equilibrium Analysis of Transmission Charge Reform in Japan's Electric Power Industry

Shu-ichi Akiyama[1,†] Nobuhiro Hosoe[2,‡]

[1] Kushiro Public University
4-1-1 Ashino, Kushiro, Hokkaido 085-8585, Japan
[2] National Graduate Institute for Policy Studies
7-22-1 Roppongi, Minato, Tokyo 106-8677, Japan

Abstract *This paper examines impacts of the regulatory reform of transmission charge schemes in Japan's electric power market. The reform intends to promote intra- and inter-regionally competition between power suppliers with postage-stamp style charges irrespective of transmission distance. It leads to extensive uses of inter-regional links to cause congestions. Congestions segment the market into several regional markets to make the reform less successful. We develop a nine-region spatial equilibrium model to simulate the reform. We found that the reform would lead to significant increases of inter-regional transmission but to cause congestion only at one link. Other links would have abundant capacity.*

Keywords electricity industry, regulatory reform, a spatial partial equilibrium model

1 Introduction

1.1 Background to Regulatory Reforms

The domestic electricity sector has been regionally monopolized by nine (and ten from 1972) vertically integrated companies, called General Electric Utilities (GEUs), in Japan. The electric power industry used to be considered a natural monopoly because of its subadditive cost structure. In principle, regional demand is met with its domestic sources held by GEU's. Recently, the situation has been reversed.

† Tel: +81-154-37-5526, Fax: +81-154-37-3287, Email: akiyama@kushiro-pu.ac.jp
‡ Corresponding author.
Tel: +81-3-6439-6129, Fax: +81-3-6439-6010, Email: nhosoe@grips.ac.jp

We no longer expect sizeable benefits from scale economies in this sector but expect such regional autarky system to be less efficient than those of the US and Europe because of a lack of competition among incumbents and entrants in and across regions. The differences in charges between these countries suggest magnitude of inefficiency of this industry in Japan. Charge differences reach 20-30%.

To tackle the inefficiency of the domestic electric power industry, the regulatory authority has permitted entry of power producers and suppliers (PPS's) who generate electricity with their own plants and/or retail power to large-scale users. In contrast, the authority did not proposing deregulation either in the transmission or the distribution sector, in which natural monopoly still prevails because of network externalities. The deregulation in the power generation sector alone does not work because transmission and distribution network is possessed by the incumbents. Free access to the network accompanied by reasonable charge schemes ensures competition among GEU's and PPS's to abolish inefficiency of this industry.

1.2 Charge Schemes for Transmission Network

A huge amount of investments has been made for development of nationwide transmission network system. To recover fixed costs of the transmission network, transmission charges are imposed. Various transmission charge schemes can be considered. While lump-sum charge schemes do not cause any distortions in resource allocation and are the most efficient scheme for recovering such fixed costs as a conventional theory tells us, the scheme can also prevent small-scale players from accessing the market. Thus, reality does not allow us to take such most efficient schemes.

Japan had employed a zone-based transmission tariff scheme of pancake pricing, which charges on volume and distance of transmission, in combination with lump-sum charges. Transmission charges are accumulated in accordance with the distance of transmission between producers and users (Table 1.1). This provides less incentive to long-distance transmission and discourages inter-regional competition. The market tends to be segmented into several regional markets with a limited number of players.

From a technological viewpoint, the distance does not necessarily matter in electric power transmission. A contract between a supplier and its user does not necessarily require transmission between them. Instead, the power injected by the producer can be extracted by other (probably near-by) users; its customer can extract power injected by other producers. This is a unique feature of electricity compared with usual commodities and provides no reason to charge transmission according to its distance.

To improve competition between all the power producers and suppliers on the network, the regulatory authority decided to replace the pancake pricing scheme with a postage-stamp one. The postage-stamp scheme charges only on transmission volume but not on distance. The charge scheme becomes more lump-sum fashion and thus more efficient than the pancake pricing scheme.

As a result, this reform can lead to extensive uses of inter-regional transmission links. This is a potential risk factor for Japan's electric power network because it is popularly recognized that the inter-regional links have had small physical capacity (Fig. 2.1). Particularly, capacity of the link between Tokyo and Chubu is less than 5% of their market sizes. This is because the link is equipped with frequency converters (FC) to connect two areas with different frequencies: 50Hz area in eastern Japan and 60Hz area in western Japan. The GEU's were against this reform anticipating excessive uses of such poor inter-regional transmission links, which can make the network system unmanageable.

However, their claim does not necessarily seem valid. Congestion can be managed by means of, for example, congestion charges, rationing, competitive bidding of transmission options, and their mixture. Moreover, Japan has historically developed electric power markets on the principle that regional demand has been mostly met with its domestic supply sources and just supplementarily with foreign sources over inter-regional links. Indeed, physical capacity of inter-regional links is small compared with the total amount generated and consumed in each region, but inter-regional transmission links might not be sp serious bottlenecks as to make the system fragile.

Economists cast a concern on the poorness of inter-regional network from another viewpoint. If the inter-regional links have small capacity compared with potential transmission demand and cause congestion, the market is segmented to reduce competitive pressure from players in other regions as it was before the transmission charge reform. Non-competitive behavior can reduce efficiency of the market. These concerns requests us to examine whether congestion can really take place under the postage-stamp pricing scheme and where bottlenecks are located, if any.

As far as the authors know, no research has been made about possibility of congestion of inter-regional links in connection with the transmission charge scheme reform in Japan. This is why, even after the postage-stamp pricing scheme has actually implemented from April 1, 2005 on, such a myth of "a poor inter-regional transmission network system in Japan" is still popular.

This motivated us to carry out a numerical simulation analysis of transmission charge scheme reform and its impacts on congestion at inter-regional links. We employ an electricity spatial and temporal price and allocation (e-STPA) model, à la Takayama and Judge (1971). In this model, there are nine regions distinguished. Each region is represented by a node and connected with others via inter-regional links. Users are located in each region and extract power from their domestic node via distribution grids. Links have their own transmission capacity. We can evaluate to what extent the links are to be occupied and congested under different transmission charge schemes.

The reference point is set at a typical peak load in summer, when we can experience the most serious congestion in Japan. By simulating this peak load situation, we can identify potential bottlenecks and draw policy implications. Our simulation results suggest that the transmission charge scheme reform toward a postage-stamp charge scheme would markedly increase uses of inter-regional transmission links by 84.3% in comparison with the situation under the original pancake pricing scheme. This would lead to congestion only at the FC-link. In contrast, we found that the other links would have abundant capacity.

This paper proceeds as follows. Section 2 explains details of our e-STPA model. Section 3 presents our simulation scenarios and results. Section 4 concludes our paper.

2 The e-STPA model

2.1 The Model Structure

Our e-STPA model distinguishes nine regions in Japan, each of which corresponds to the jurisdiction of an individual GEU (1: Hokkaido, 2: Tohoku, 3: Tokyo, 4: Chubu, 5: Hokuriku, 6: Kansai, 7: Chugoku, 8: Shikoku, and 9: Kyushu)[1]. Regions are connected with each other via nine inter-regional transmission links. In each region, users extract power via domestic distribution grids. Two logical links are defined on each physical inter-regional link to identify direction of power flow. The topology of the network is summarized in Fig. 2.1[2].

Each region has a pair of inverse supply and demand functions (2.1) and (2.2), expressed in a non-linear complementarity format as follows:

* supply function

$$\begin{aligned} &\left(-p_i^y + p_i^y(\cdot)\right)y_i = 0, \\ &-p_i^y + p_i^y(\cdot) \geq 0, \qquad (2.1) \\ &y_i \geq 0 \end{aligned}$$

* demand function

$$\begin{aligned} &\left(p_i^x - \left(A_i^x + B_i^x x_i\right)\right)x_i = 0, \\ &p_i^x - \left(A_i^x + B_i^x x_i\right) \geq 0, \qquad (2.2) \\ &x_i \geq 0 \end{aligned}$$

The supply function $p_i^y(\cdot)$ describes merit-order of power plants located in each region. Electric power generated in the i-th region y_i is distributed to its own and other regions $\sum_j z_{i,j}$ as (2.3) shows. In addition, losses accruing

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1 There is another region of Okinawa. Because Okinawa is isolated from the other nine regions on the Japanese mainland, we do not include it in our analysis.

2 We omit another link between Hokuriku and Chubu partly because the link has a small capacity and partly because they can carry out transmission between these regions via Kansai, too.

from outbound inter-regional transmission $\sum_{j\neq i}\Omega_{i,j}{z_{i,j}}^2$ are taken into account by employing a quadratic function. Equation (2.4) shows that consumption in this region x_i cannot exceed total power shipped from all the regions to the i-th region $\sum_j z_{j,i}$ less the corresponding transmission losses $\sum_j w_i z_{j,i}$.

* Market-clearing conditions

$$\begin{aligned}
&\left(y_i - \sum_j z_{i,j} - \sum_{j\neq i}\Omega_{i,j}{z_{i,j}}^2\right)p_i^y = 0,\\
&y_i - \sum_j z_{i,j} - \sum_{j\neq i}\Omega_{i,j}{z_{i,j}}^2 \geq 0, \qquad (2.3)\\
&p_i^y \geq 0
\end{aligned}$$

$$\begin{aligned}
&\left(-x_i + \sum_j z_{j,i} - w_i\sum_j z_{j,i}\right)p_i^x = 0,\\
&-x_i + \sum_j z_{j,i} - w_i\sum_j z_{j,i} \geq 0, \qquad (2.4)\\
&p_i^x \geq 0
\end{aligned}$$

Exogenous transmission capacity $z_{i,j}^{up}$ is set to each inter-regional link (2.5). When there is no more room to transmit via this link, its shadow price of this capacity constraint $r_{i,j}$ arises. This can be interpreted as congestion charges. The independent system operator might not explicitly impose congestion charges in practice but employ some other schemes to manage congestion for example, rationing schemes. In this case, corresponding quasi-rents arise at the same magnitude to play the same role with congestion charges.

* Transmission capacity constraint

$$\begin{aligned}
&\left(z_{i,j}^{up} - z_{i,j}\right)r_{i,j} = 0,\\
&z_{i,j}^{up} - z_{i,j} \geq 0,\\
&r_{i,j} \geq 0
\end{aligned}$$

(2.5)

When transmission from the i-th region to the j-th region takes place $z_{i,j} > 0$, consumer price of electricity in the j-th region p_j^x is equal to its supply price in i-th region p_i^y with transmission charges $t_{i,j}$, congestion charges $r_{i,j}$, shadow prices of outbound $2\Omega_{i,j}p_i^y z_{i,j}$, and inbound transmission losses $w_j p_j^x$ as shown in (2.6). When there is no transmission from the i-th region to the j-th region $z_{i,j}=0$, this inter-regional price linkage does not necessarily hold but allows the consumer price p_j^x to be lower than the producer price p_i^y plus transmission-related costs. In the case of intra-regional transmission, losses are not considered in this supply side but in demand side.

* Price equilibrium condition

$$
\begin{aligned}
&\left(-p_j^x + p_i^y + t_{i,j} + r_{i,j} + 2\Omega_{i,j} p_i^y z_{i,j} + p_j^x w_j\right) z_{i,j} = 0, \\
&-p_j^x + p_i^y + t_{i,j} + r_{i,j} + 2\Omega_{i,j} p_i^y z_{i,j} + p_j^x w_j \geq 0, \\
&z_{i,j} \geq 0 \\
&\forall i \neq j \\
&\left(-p_j^x + p_i^y + t_{i,j} + p_j^x w_j\right) z_{i,j} = 0, \\
&-p_j^x + p_i^y + t_{i,j} + p_j^x w_j \geq 0, \\
&z_{i,j} \geq 0 \\
&\forall i = j
\end{aligned}
\tag{2.6}
$$

Notations are:

* sets

i, j: regions

* endogenous variables

y_i: production in the i-th region

x_i: consumption in the i-th region

$z_{i,j}$: transmission from the i-th region to the j-th region

p_i^y: producer prices in the i-th region

p_i^x: consumer prices in the i-th region

$r_{i,j}$: congestion charges at the link from the i-th region to the j-th region

* exogenous variables/constants

A_i^x: constant terms of demand function in the i-th region

B_i^x: slope parameters of demand function in the i-th region

$t_{i,j}$: transmission charges from the i-th region to the j-th region

$\Omega_{i,j}$: loss parameters for inter-regional outbound transmission

w_i: parameters for inbound transmission

$z_{i,j}^{up}$: transmission capacity

The inter-regional relationships can be graphically confirmed in Fig 2.2. The gap between domestic production y_i and consumption x_i corresponds to the amount of exporting transmission to the other region $z_{i,j}$. This must be equal to the importing transmission in the other region, which corresponds to the gap between its production y_j and consumption x_j, too. The producer price p_i^y plus transportation cost $t_{i,j}$ is exactly equal to the consumer price in the other region p_j^x because inter-regional transmission takes place $z_{i,j} > 0$ in this figure (omitting transmission losses and congestion here). The consumer price p_j^x is also equal to its domestic producer prices p_j^y plus its domestic transmission cost $t_{j,j}$. This inter-price linkage ensures that domestic producers can be as much competitive as foreign producers, too.

2.2 Model Calibration

We developed supply functions (2.1) on the basis of merit-order curves considering all the thermal plants of the GEU's and large-scale wholesalers, while assuming nuclear, IPP's thermal, and hydro plants except for pumped-storage ones are low-cost must-run plants. The reference load is set at the three-day average hourly peak load in each region. Price elasticities in the demand functions (2.2) are econometrically estimated for each region and converted into slope parameters at the peak load of each region. Intercept terms are calibrated to the peak load, too[3]. Outbound transmission loss parameters $\Omega_{i,j}$ are calibrated to an average occupation rate of transmission links (19%) and the corresponding loss rate (2%),

[3] The price elasticity is reported in Appendix I with results of its econometric diagnostics tests.

assuming quadratic transmission loss functions shown in (2.3). Inbound transmission loss rates w_i are set at a constant rate of 2%.

When we analyze Japan's electric power markets, it is essential to take account of long-term large-volume wholesale contracts across regions. This is because such contracts presuppose the top priority of their transmission in occupation of inter-regional links. There are two cases considered: supply from Kyushu to regions in western Japan (1,800MW) and that from Shikoku to Kansai (1,400MW). In our model, we treat these contracts as if must-run plants with these capacities were located in Chugoku and in Kansai. In addition, the transmission capacities for the links from Kyushu to Chugoku and from Shikoku to Kansai shown in Fig. 2.1 are reduced as reserves. At the same time, capacity of must-run plants in Kyushu and Shikoku is reduced; the capacity of the links for the opposite directions is increased. These treatments result in excluding such power flow from our model and simulation results.

3 Simulation

3.1 Simulation Scenario and the Base Run

The pancake pricing scheme shown in Table 1.1 was replaced with the postage-stamp scheme in 2005. The postage-stamp scheme charges constant transmission tariffs irrespective of distance. The network operator has to earn a certain amount of revenues to recover fixed costs of transmission network[4]. Therefore, the postage-stamp transmission charge is calculated so that the amount of transmission and congestion charge revenues are exactly equal to those under the pancake pricing scheme.

The Base Run solution is shown in Fig. 3.1. There is a small amount of inter-regional transmission in western Japan, which is a 60Hz frequency area consisting of Chubu, Kansai, Hokuriku, Shikoku, Chugoku, and Kyushu. Inter-regional power flow appears from Chubu to Kansai by 147MW. No congestion is caused by such little inter-regional transmission as the original regional autarky system was designed.

In eastern Japan, which is a 50Hz frequency area consisting of Hokkaido, Tohoku, and Tokyo, heavy transmission from Tohoku to Tokyo appears. Occupancy of the link reaches 75%.

Due to the frequency converter between Tokyo and Chubu, high transmission charges are imposed and prevent transmission between the western and eastern areas

[4] In reality, there is no independent network operator. Instead, the GEU's earn and redistribute the transmission charges among them to adjust imbalances between their fixed costs and charge earnings. In our simulations, we suppose there is a virtual independent network operator who controls power flows and collect transmission and congestion charges.

even though the producer price in Chubu (4.86 yen/kWh) is much lower than that in Tokyo (6.85 yen/kWh). High transmission charges under pancake pricing scheme suppress inter-regional transmission as we discussed. The amount of inter-regional transmission amounts to 4,648MW, which is only 2.6% of the total amount of power generated in Japan.

3.2 The Reform for the Postage-stamp Pricing Scheme

In the Counter-factual Run, the pancake style transmission charges shown in Table 1.1 (1.19-7.39 yen/kWh) are replaced with a uniform postage-stamp charge (1.45 yen/kWh). Charges for long distance transmission are lowered to stimulate inter-regional transmission. As a result, all the inter-regional links would be utilized (Fig. 3.2). The total amount of inter-regional transmission would reach 8,567MW, which is 84.3% more than that in the Base Run.

In the western area, Kansai would intensify its imports not only from its near-by regions but also distant regions indirectly. However, there would not be any inter-regional links which hit their capacity ceiling. Inter-regional transmission in the eastern area would increase generally. The occupation rate of the link from Hokkaido to Tohoku would surge up to 53.0%. In contrast, the link from Tohoku to Tokyo would not increase so drastically. This is because transmission from Chubu via the FC-link would be competitive enough to prevent further sizable imports from Tohoku.

Attention should be paid to congestion at the FC-link between the eastern and western areas. The frequency converter would be in full operation to experience heavy congestion which would require congestion charges as high as 0.39 yen/kWh. The producer price offered in Chubu (4.92 yen/kWh) would be marked up with congestion charges by 7.9% as well as with a high loss rate by 21.0%. Its congestion would cause a serious price gap between western and eastern Japan.

Generally, imports enable domestic consumers to enjoy lower prices to increase consumer surplus. Exports raise supply prices to favor producers. However, Chubu would be exceptional. Both of producer and consumer surpluses would increase. The congestion at the FC-link would have surplus captured not by producers in Chubu but by the network operator as congestion charges. The congestion charge would play a role of export taxes to lower the domestic price. Resources would be directed to its domestic market and let consumers in Chubu gain, too.

4 Concluding Remarks

Simulating transmission patterns under two different transmission charge schemes, we found that no serious congestion would take place even under the postage-stamp pricing scheme at any links but only at the FC-link between Chubu and Tokyo. To manage the congestion, we have to impose congestion charges of 0.39 yen/kWh.

Our simulation result suggests that most inter-regional links should not be regarded poor but have abundant capacity. Within each of eastern and western areas, this concern would not be valid. The abundant capacity could allow further deregulation which presupposes inter-regional competition. On the other hand, limited transmission capacity leads to imperfect competition and decreases benefits of regulatory reforms. Actually, the congestion at the FC-link could allow Tokyo to exercise monopolistic power in its domestic market. We need to keep a special eye on non-competitive behavior there.

This is a simulation for a typical peak load. Load is much light in other situations; so is congestion. Our simulations can be also applied to the other situations: off-peak, daytime and night. Covering all the situations and summing up welfare changes in all the situations for a year, we can finally evaluate overall costs and benefits of the regulatory reform in transmission charge schemes.

Our simulations do not consider any uncertainty and its impacts on inter-regional transmission patterns. As network operators concern, unscheduled shutdown of large-scale nuclear plants —— which actually took place in 2004 —— can be critical for power markets. Under the regulatory regime, each regional power company used to be solely responsible for meeting demand in its own region. Now the responsibility is supposed to be pooled by all the power producers integrated with inter-regional transmission to increase efficiency. By perturbing demand and supply, we can also evaluate robustness of the network under such uncertainty.

Appendix I: Estimation of Demand Price Elasticity

We estimate the following demand functions for each region i :

$$Q_i = a_i + b_i \cdot \log(GDP)_i + g_i \cdot \log(Poil) + d_i \cdot \log(DAY_i) + e_i \cdot \log(p_i)$$

where Q_i is the index of power demand excluding lighting service, GDP_i is real gross regional product, $Poil$ is the wholesale price index of heavy oil, which is common across regions, DAY_i is sum of the summer days and the winter days, and p_i is the index of regional power price. Price elasticity e_i is estimated for each region i and employed for calibration of demand functions (2.2).

Durbin-Watson statistics indicate a serial correlation in residuals in plain ordinary panel estimates. To overcome the serial correlation, we employ the generalized method of moments (GMM). The GMM estimates satisfy overidentifying restrictions. All of our estimates of price elasticity and the others are significant and reasonable in their sign (Table I).

Table I: Estimation Results (Dependent Variable: Q_i)

Regions	Constant	GDP_i	$Poil_i$	DAY_i	p_i	Adjusted R^2	EG tests
Hokkaido	-2.5379 [.000]	0.6144 [.000]	0.3165 [.000]	0.0461 [.192]	-0.4547 [.000]	0.990	-2.209 (0.909)
Tohoku	-4.4147 [.000]	0.6945 [.000]	0.2879 [.000]	0.1074 [.001]	-0.4034 [.000]	0.990	-3.042 (0.577)
Tokyo	-6.0157 [.000]	0.7109 [.000]	0.1988 [.000]	0.1070 [.001]	-0.2370 [.000]	0.995	-2.121 (0.927)
Chubu	-3.6418 [.000]	0.6261 [.000]	0.1556 [.000]	0.0771 [.034]	-0.2722 [.000]	0.993	-3.731 (0.231)
Hokuriku	-0.0728 [.788]	0.4532 [.000]	0.1062 [.000]	0.0572 [.059]	-0.3111 [.000]	0.978	-2.978 (0.611)
Kansai	-3.6826 [.000]	0.5617 [.000]	0.1409 [.000]	0.1436 [.002]	-0.1595 [.006]	0.990	-3.991 (0.140)
Chugoku	-1.5248 [.014]	0.5042 [.000]	0.2639 [.000]	0.0915 [.272]	-0.4176 [.000]	0.950	-2.021 (0.944)
Shikoku	-0.6365 [.076]	0.4603 [.000]	0.2846 [.000]	0.1145 [.016]	-0.4575 [.000]	0.972	-3.645 (0.266)
Kyushu	-5.2881 [.000]	0.7455 [.000]	0.2634 [.000]	0.1302 [.030]	-0.3606 [.000]	0.990	-2.187 (0.914)

NOTE: P-values are in brackets. Lower tail area of Engle-Granger tests are in parentheses.

Data Sources

(1) Electric power quantity, capacity, revenues, and costs

Agency of Natural Resources and Energy (ANRE) Abstract of Electric Power Industry (Denryoku-Jyukyu-no-Gaiyou).

The Federation of Electric Power Companies Hand Book of Electric Power Industry (Denki-Jigyou-Binran).

(2) Prefectural economic data

Asahi Newspaper, *National Power (Minryoku)*.

National Astronomical Observatory, Annual Report Prefectural Accounts (Kemmin-Keizai-Keisan-Nempo), Chronological Scientific Tables (Rika-Nempo), Maruzen.

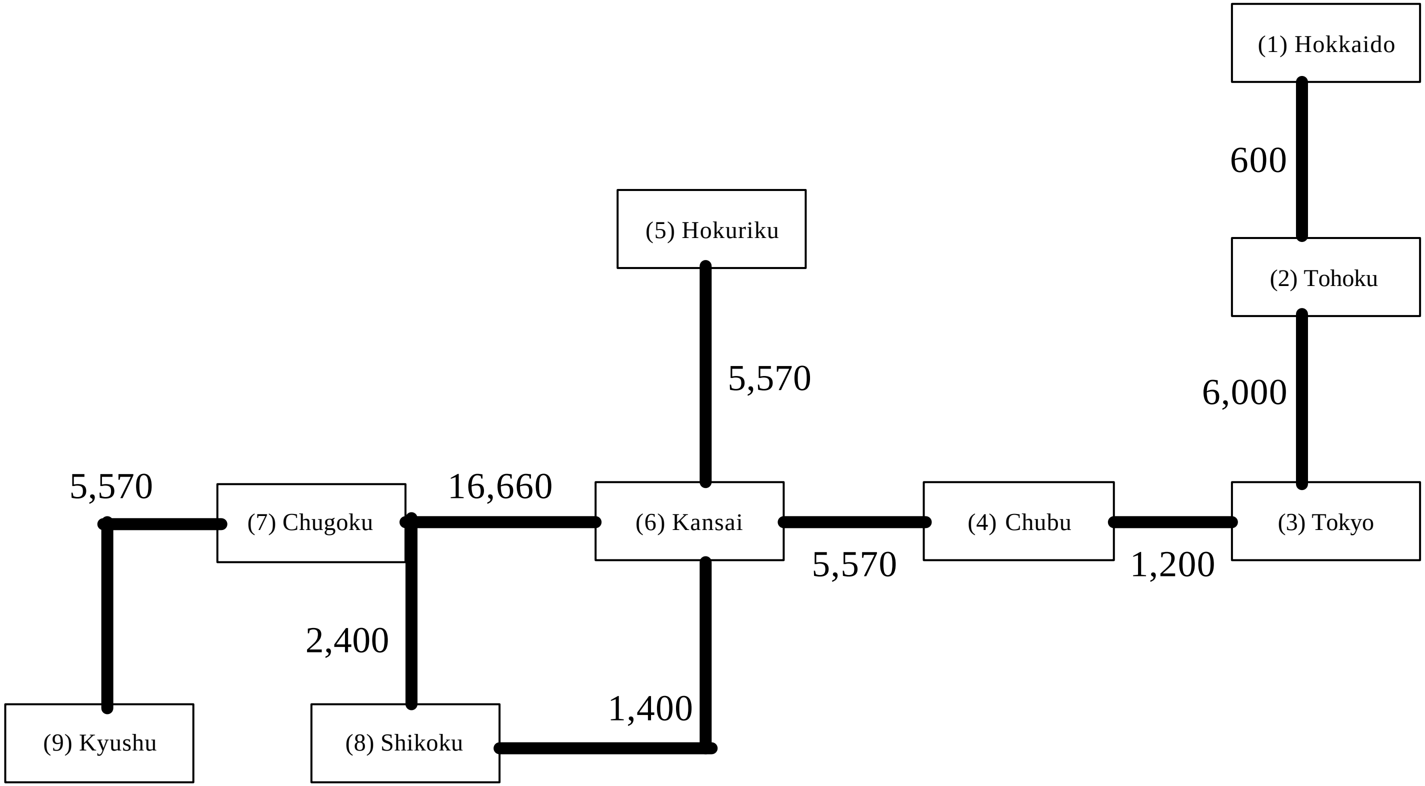
Research and Statistics Department *Price Indexes Monthly (Bukka-Shisu-Geppo)*, Bank of Japan.

Table 1.1: Transmission Charges under-the Pancake Pricing Scheme (yen/kWh)

From/To	Hokkaido	Tohoku	Tokyo	Chubu	Hokuriku	Kansai	Chugoku	Shikoku	Kyushu
Hokkaido	1.50	3.36	3.90	5.91	6.09	5.94	6.16	6.88	6.57
Tohoku	3.55	1.41	1.95	3.96	4.14	3.99	4.21	4.93	4.62
Tokyo	3.84	1.70	1.53	3.54	3.72	3.57	3.79	4.51	4.20
Chubu	5.85	3.71	3.54	1.59	1.77	1.62	1.84	2.56	2.25
Hokuriku	6.37	4.23	4.06	2.11	1.23	1.60	1.82	2.54	2.23
Kansai	6.15	4.01	3.84	1.89	1.53	1.38	1.60	2.32	2.01
Chugoku	6.53	4.39	4.22	2.27	1.91	1.76	1.30	2.41	1.71
Shikoku	7.39	5.25	5.08	3.13	2.77	2.62	2.47	1.19	2.88
Kyushu	6.84	4.70	4.53	2.58	2.22	2.07	1.61	2.72	1.33

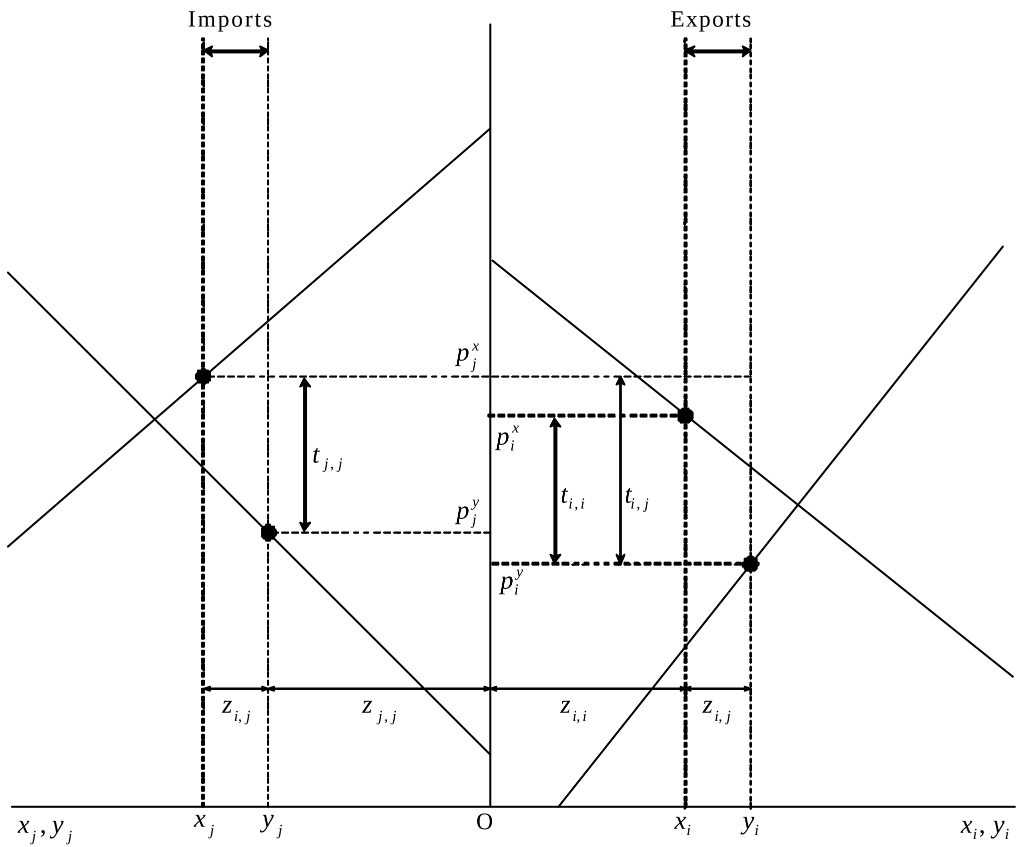
Source: Wheeling and access charges as of April 2004 compiled by the authors.

Figure 2.1: Capacity of Inter-regional Transmission Links (MW)



Source: CEPC (2002)

Figure 2.2: the e-STPA Model ––– Two Regions Case –––



Note: transmission losses and capacity constraints are omitted for simplicity of the figure.

Figure 3.1: The Base Run under the Pancake Pricing Scheme

Total			
Procuction	(MW)	177,737	-
Consumption	(MW)	173,834	-
Transmission Losses	(MW)	3,905	-
Inter-reg. Transmission	(MW)	4,648	-
Welfare	(mil. yen)	2,830.9	-
Producer Surplus	(mil. yen)	626.1	-
Consumer Surplus	(mil. yen)	2,204.8	-
Ntwk Op. Surplus	(mil. yen)	0.0	-
Tran. Charg. Rev.	(mil. yen)	258.6	-
Netwk. Fixed Cost	(mil. yen)	-258.6	-
Postage Stamp Price	(yen/kWh)	-	-

Hokkaido		
Production	4,783	-
Consumption	4,688	-
Prod. Price	4.65	-
Cons. Price	6.27	-
Welfare	55.6	-
Prod. Surp.	19.9	-
Cons. Surp.	35.8	-

Hokuriku		
Production	5,480	-
Consumption	5,371	-
Prod. Price	5.25	-
Cons. Price	6.61	-
Welfare	80.8	-
Prod. Surp.	24.0	-
Cons. Surp.	56.8	-

Transmission	0
Occup. Rate	0.0%
Loss Rate	0.0%
Cong. Charg.	0.00

Transmission	0
Occup. Rate	0.0%
Loss Rate	0.0%
Cong. Charg.	0.00

Kansai		
Production	31,827	-
Consumption	31,334	-
Prod. Price	5.13	-
Cons. Price	6.64	-
Welfare	746.5	-
Prod. Surp.	90.4	-
Cons. Surp.	656.1	-

Tohoku		
Production	19,307	-
Consumption	14,160	-
Prod. Price	5.55	-
Cons. Price	7.11	-
Welfare	185.5	-
Prod. Surp.	66.8	-
Cons. Surp.	118.7	-

Transmission	0
Occup. Rate	0.0%
Loss Rate	0.0%
Cong. Charg.	0.00

Transmission	147
Occup. Rate	3.0%
Loss Rate	1.0%
Cong. Charg.	0.00

Chugoku		
Production	11,682	-
Consumption	11,448	-
Prod. Price	4.78	-
Cons. Price	6.21	-
Welfare	127.8	-
Prod. Surp.	41.3	-
Cons. Surp.	86.5	-

Chubu		
Production	27,735	-
Consumption	27,036	-
Prod. Price	4.86	-
Cons. Price	6.58	-
Welfare	381.9	-
Prod. Surp.	60.7	-
Cons. Surp.	321.2	-

Transmission	0
Occup. Rate	0.0%
Loss Rate	0.0%
Cong. Charg.	0.00

Transmission	0
Occup. Rate	0.0%
Loss Rate	0.0%
Cong. Charg.	0.00

Transmission	4,502
Occup. Rate	75.0%
Loss Rate	16.0%
Cong. Charg.	0.00

Kyushu		
Production	16,489	-
Consumption	16,160	-
Prod. Price	4.85	-
Cons. Price	6.31	-
Welfare	207.1	-
Prod. Surp.	54.5	-
Cons. Surp.	152.6	-

Transmission	0
Occup. Rate	0.0%
Loss Rate	0.0%
Cong. Charg.	0.00

Shikoku		
Production	6,050	-
Consumption	5,929	-
Prod. Price	4.20	-
Cons. Price	5.50	-
Welfare	59.1	-
Prod. Surp.	18.0	-
Cons. Surp.	41.1	-

Transmission	0
Occup. Rate	0.0%
Loss Rate	0.0%
Cong. Charg.	0.00

Tokyo		
Production	54,384	-
Consumption	57,708	-
Prod. Price	6.85	-
Cons. Price	8.55	-
Welfare	986.6	-
Prod. Surp.	250.7	-
Cons. Surp.	735.9	-

Unit: Production, Consumption, and Transmission (MW), Prices (yen/kWh), Welfare and Surpluses (mil. yen).

Figure 3.2: Counter-factual Run under the Postage-stamp Pricing Scheme

Total			
Procuction	(MW)	178,828	(0.6%)
Consumption	(MW)	174,712	(0.5%)
Transmission Losses	(MW)	4,116	(5.4%)
Inter-reg. Transmission	(MW)	8,567	(84.3%)
Welfare	(mil. yen)	2,833.1	(0.1%)
Producer Surplus	(mil. yen)	597.5	(-4.6%)
Consumer Surplus	(mil. yen)	2,235.6	(1.4%)
Ntwk Op. Surplus	(mil. yen)	0.0	-
Tran. Charg. Rev.	(mil. yen)	258.6	-
Netwk. Fixed Cost	(mil. yen)	-258.6	-
Postage Stamp Price	(yen/kWh)	1.45	-

Hokkaido		
Production	5,058	(5.7%)
Consumption	4,625	(-1.3%)
Prod. Price	4.90	(5.4%)
Cons. Price	6.48	(3.3%)
Welfare	56.1	(0.9%)
Prod. Surp.	21.3	(7.3%)
Cons. Surp.	34.8	(-2.7%)

Transmission	231
Occup. Rate	4.0%
Loss Rate	1.0%
Cong. Charg.	0.00

Hokuriku		
Production	5,254	(-4.1%)
Consumption	5,376	(0.1%)
Prod. Price	5.01	(-4.5%)
Cons. Price	6.59	(-0.3%)
Welfare	79.2	(-2.0%)
Prod. Surp.	22.3	(-7.3%)
Cons. Surp.	56.9	(0.2%)

Transmission	321
Occup. Rate	53.0%
Loss Rate	11.0%
Cong. Charg.	0.00

Transmission	1,391
Occup. Rate	8.0%
Loss Rate	2.0%
Cong. Charg.	0.00

Kansai		
Production	30,612	(-3.8%)
Consumption	31,404	(0.2%)
Prod. Price	4.97	(-3.1%)
Cons. Price	6.55	(-1.4%)
Welfare	744.3	(-0.3%)
Prod. Surp.	85.3	(-5.6%)
Cons. Surp.	659.0	(0.4%)

Transmission	274
Occup. Rate	5.0%
Loss Rate	1.0%
Cong. Charg.	0.00

Tohoku		
Production	19,260	(-0.2%)
Consumption	14,217	(0.4%)
Prod. Price	5.45	(-1.9%)
Cons. Price	7.04	(-0.9%)
Welfare	184.4	(-0.6%)
Prod. Surp.	64.7	(-3.0%)
Cons. Surp.	119.6	(0.8%)

Transmission	108
Occup. Rate	3.0%
Loss Rate	1.0%
Cong. Charg.	0.00

Chugoku		
Production	12,427	(6.4%)
Consumption	11,255	(-1.7%)
Prod. Price	4.88	(2.1%)
Cons. Price	6.46	(4.1%)
Welfare	126.2	(-1.3%)
Prod. Surp.	42.6	(3.1%)
Cons. Surp.	83.6	(-3.3%)

Transmission	0
Occup. Rate	23.0%
Loss Rate	5.0%
Cong. Charg.	0.00

Chubu		
Production	29,290	(5.6%)
Consumption	27,135	(0.4%)
Prod. Price	4.92	(1.2%)
Cons. Price	6.50	(-1.3%)
Welfare	385.9	(1.1%)
Prod. Surp.	62.4	(2.8%)
Cons. Surp.	323.6	(0.7%)

Transmission	4,688
Occup. Rate	78.0%
Loss Rate	16.0%
Cong. Charg.	0.00

Kyushu		
Production	16,493	(0.0%)
Consumption	16,056	(-0.6%)
Prod. Price	4.85	(0.0%)
Cons. Price	6.43	(1.9%)
Welfare	205.1	(-0.9%)
Prod. Surp.	54.5	(0.0%)
Cons. Surp.	150.7	(-1.3%)

Transmission	353
Occup. Rate	15.0%
Loss Rate	3.0%
Cong. Charg.	0.00

Shikoku		
Production	6,055	(0.1%)
Consumption	5,582	(-5.8%)
Prod. Price	4.74	(12.8%)
Cons. Price	6.31	(14.7%)
Welfare	57.7	(-2.4%)
Prod. Surp.	21.2	(18.1%)
Cons. Surp.	36.4	(-11.4%)

Transmission	1,200
Occup. Rate	100.0%
Loss Rate	21.0%
Cong. Charg.	0.39

Tokyo		
Production	54,379	(-0.0%)
Consumption	59,061	(2.3%)
Prod. Price	6.35	(-7.4%)
Cons. Price	7.95	(-7.0%)
Welfare	994.1	(0.8%)
Prod. Surp.	223.3	(-10.9%)
Cons. Surp.	770.9	(4.7%)

Unit: Production, Consumption, and Transmission (MW), Prices (yen/kWh), Welfare and Surpluses (mil. yen).