The Deregulation of Japan's Electricity Industry

Annex for the Original Article in *Japan and the World Economy*

August 26, 2004

Nobuhiro Hosoe

Associate Professor
National Graduate Institute for Policy Studies
nhosoe@grips.ac.jp

Appendix I: The Detailed Equation List

[The Household Consumption[1]]

- The demand function for non-energy goods

$$X^{p}_{ni2} = \alpha_{ni2}\left(\sum_{h,j} p^{f}_{h,j} F_{h,j} - S - T^{d}\right) / \, p^{q}_{ni2} \tag{1}$$

- The demand function for the energy composite

$$X^{pEn} = \alpha^{En}\left(\sum_{h,j} p^{f}_{h,j} F_{h,j} - S - T^{d}\right) / \, p^{xpEn} \tag{2}$$

[The Energy Composite Aggregation for the Household]

- The energy composite aggregation function for the household

$$X^{pEn} = o^{p}\left(\sum_{ei2} \psi^{p}_{ei2} X^{p}_{ei2}{}^{\chi^{p}}\right)^{1/\chi^{p}} \tag{3}$$

- The energy goods demand function

$$X^{p}_{ei2} = \left(\frac{o^{p\chi^{p}} \psi^{p}_{ei2} p^{xpEn}}{(1+\upsilon_{ei2}) p^{q}_{ei2}}\right)^{1/(1-\chi^{p})} X^{pEn} \tag{4}$$

---

[1] In their background, we assume the following household utility function:

$$U = \left(X^{pEn}\right)^{\alpha^{En}} \prod_{ni2} X^{p}_{ni2}{}^{\alpha_{ni2}},$$

where U denotes utility.

[The Domestic Production]

- The fixed-coefficient value added demand function

(5) $$Y_j = ay_j Z_j$$

- The fixed-coefficient non-energy intermediate demand function by the non-energy sectors

(6) $$X_{ni,nj} = ax_{ni,nj} Z_j$$

- The fixed-coefficient energy composite demand function by the non-energy sectors

(7) $$X_{nj}^{En} = axEn_{nj} Z_{nj}$$

- The fixed-coefficient intermediate demand function by the energy sectors

(8) $$X_{i,ej} = ax_{i,ej} Z_{ej}$$

- The value added aggregation function

(9) $$Y_j = b_j \prod_h F_{h,j}^{\beta_{h,j}}, \quad \forall j \neq ETR, EDS$$

- The primary factor demand function

(10) $$F_{h,j} = \frac{\beta_{h,j} p_j^y}{p_{h,j}^f} Y_j, \quad \forall j \neq PGN, ETR, EDS$$

(for the power generation sector)

(11) $$F_{h,j} = \frac{\beta_{h,j} p_j^y Y_j + \upsilon_j p_j^q X_i^p}{p_{h,j}^f}, \quad \forall j = PGN, h = CAP$$

(12) $$F_{h,j} = \frac{\beta_{h,j} p_j^y}{p_{h,j}^f} Y_j, \quad \forall j = PGN, h = LAB$$

- The primary factor demand functions and zero profit conditions for the *ETR* and the *EDS*

(13) $$p_j^Y Y_j = \sum_h p_{h,j}^f F_{h,j}, \quad \forall j = ETR, EDS$$

(14) $$F_{Capital,j} = F_{Capital,j}^0, \quad \forall j = ETR, EDS$$

(15) $$F_{Labor,j} = Y_j / b_j, \quad \forall j = ETR, EDS$$

- The unit cost function for the non-energy sectors

(16) $$p_{nj}^z = ay_{nj} p_{nj}^y + \sum_{ni} ax_{ni,nj} p_{ni}^q + axEn_{nj} p_{nj}^{xEn}$$

- The unit cost function for the energy sectors

(17) $$p_{ej}^z = ay_{ej} p_{ej}^y + \sum_i ax_{i,ej} p_i^q$$

[The Energy Composite Aggregation for Production Sectors]

- The energy composite aggregation function for the non-energy sectors

(18) $$X_{nj}^{En} = o_{nj} \left(\sum_{ei} \psi_{ei,nj} X_{ei,nj}^{\chi} \right)^{1/\chi}$$

- The energy good demand function

(19) $$X_{ei,nj} = \left(\frac{o_{nj}^{\chi} \psi_{ei,nj} p_{nj}^{xEn}}{p_{ei}^q} \right)^{1/(1-\chi)} X_{nj}^{En}$$

[The Government Behavior]

- The government budget constraint

(20) $$T^d = \sum_i p_i^q X_i^g - \sum_i T_i^m - \sum_j T_j$$

- The government consumption

(21) $X_i^g = X_i^{g0}$

- The indirect tax revenue function

(22) $T_i = \tau_i p_i^z Z_i$

- The import tariff revenue function

(23) $T_i^m = \tau_i^m p_i^m M_i$

[Investment Behavior]

(24) $X_i^v = X_i^{v0}$

[International Trade]

- Price conversion functions between prices in JPY and in USD

(25) $p_i^e = \varepsilon p_i^{We}$

(26) $p_i^m = \varepsilon p_i^{Wm}$

- The BOP constraint (redundant)

(27) $\sum_i p_i^{We} E_i + S^f = \sum_i p_i^{Wm} M_i$

- The import good supply function of the non-electricity goods

(28) $$\left(\frac{p_{nl}^{Wm}}{p_{nl}^{Wm0}} \right)^{\sigma_{nl}} = \frac{M_{nl}}{M_{nl}^{0}}$$

- The export good demand function of the non-electricity goods

(29) $$\left(\frac{p_{nl}^{We}}{p_{nl}^{We0}} \right)^{-\sigma_{nl}} = \frac{E_{nl}}{E_{nl}^{0}}$$

- The import and export of the electricity goods

(30) $$M_{el} = M_{el}^{0}$$

(31) $$E_{el} = E_{el}^{0}$$

[Armington's Composite Good Aggregation[2]]

---

[2] In addition, we have one treatment different from usual CGE models. We do not employ the Armington (1969) structure in international trade of electricity while we assume this structure for the other commodities. This special treatment is made for the following reason. Input-output tables, which are our main data source, report international trade of such a non-tradable good as electricity. They show a small amount of uses of electricity by foreign people who live/travel in Japan and by Japanese people who travel/live abroad. We do not want such minor uses of electricity to crucially affect our empirical results; we fix these uses in quantity and assume common prices for both domestically used and (seemingly) internationally traded electricity.

- The Armington's aggregation function

(32) $$Q_{nl} = \gamma_{nl}\left(\delta_{nl}^{m} M_{nl}^{\ \eta_{nl}} + \delta_{nl}^{d} D_{nl}^{\ \eta_{nl}}\right)^{1/\eta_{nl}}$$

- The import demand function of the non-electric goods

(33) $$M_{nl} = \left(\frac{\gamma_{nl}^{\ \eta_{nl}} \delta_{nl}^{m} p_{nl}^{q}}{(1+\tau_{nl}^{m}) p_{nl}^{m}}\right)^{1/(1-\eta_{nl})} Q_{nl}$$

- The domestic good demand function of the non-electric goods

(34) $$D_{nl} = \left(\frac{\gamma_{nl}^{\ \eta_{nl}} \delta_{nl}^{d} p_{nl}^{q}}{p_{nl}^{d}}\right)^{1/(1-\eta_{nl})} Q_{nl}$$

- The market clearing conditions of the electric good

(35) $$Q_{el} = D_{el} + M_{el}$$

(36) $$(1+\tau_{el}^{m}) p_{el}^{m} = p_{el}^{q}$$

[Transformation Functions]

- The transformation function among exports and domestic supply

(37) $$Z_{nl} = \theta_{nl}\left(\xi_{nl}^{e} E_{nl}^{\ \phi_{nl}} + \xi_{nl}^{d} D_{nl}^{\ \phi_{nl}}\right)^{1/\phi_{nl}}$$

- The export supply function

(38) $$E_{nl} = \left(\frac{\theta_{nl}^{\ \phi_{nl}} \xi_{nl}^{e} (1+\tau_{nl}) p_{nl}^{z}}{p_{nl}^{e}}\right)^{1/(1-\phi_{nl})} Z_{nl}$$

- The domestic good supply function

(39) $$D_{nl} = \left(\frac{\theta_{nl}^{\phi_{nl}} \xi_{nl}^{d} (1+\tau_{nl}) p_{nl}^{z}}{p_{nl}^{d}} \right)^{1/(1-\phi_{nl})} Z_{nl}$$

- The market clearing conditions for the electric good

(40) $$Z_{el} = E_{el} + D_{el}$$

(41) $$p_{el}^{e} = (1+\tau_{el}) p_{el}^{z}$$

(42) $$p_{el}^{q} = (1+\tau_{el}) p_{el}^{z}$$

(43) $$p_{el}^{d} = (1+\tau_{el}) p_{el}^{z}$$

[The Market Clearing Conditions]

- Goods

(44) $$Q_i = X_i^p + X_i^g + X_i^v + \sum_j X_{i,j}$$

- Primary factors

(45) $$FF_h = \sum_j F_{h,j}$$

- Factor prices

(46) $$p_{Labor,j}^{f} = p_{Labor,i}^{f}, \quad \forall i, j$$

(47) $$p_{Capital,j}^{f} = p_{Capital,i}^{f}, \quad \forall i, j \neq ETR, EDS$$

[The Private Saving]

(48) $$S = \sum_i p_i^q X_i^v - \left(S^g + \varepsilon S^f\right)$$

[The ROR Regulation on the ETR and the EDS Sectors]

(49) $$p^f_{Capical,j} = \frac{p_j^{z0} Z_j^0 - \left(\sum_i p_i^{q0} X_{i,j}^0 + p_{Labor}^{f0} F_{Labor,j}^0\right)}{F_{Capital,j}^{f0}}, \quad j = ETR, EDS$$

[The Household Electricity Charge Pegging Equation]

(50) $$\frac{\left(1+\upsilon_{PGN}\right) p_{PGN}^q X_{PGN}^p}{\sum_{i \neq PGN} p_i^q X_i^p} = \frac{p_{PGN}^{q0} X_{PGN}^{p0}}{\sum_{i \neq PGN} p_i^{q0} X_i^{p0}}$$

[The Numéraire]

(51) $$\sum_{nl} p_{nl}^z Z_{nl}^0 = \sum_{nl} p_{nl}^{z0} Z_{nl}^0$$

[Notations]

Sets

i, j: Goods and sectors (listed in Table 2),

ei, ej: Energy goods and sectors, i.e., {COL, OIL, PGN, ETR, EDS, GAS},

ni, nj: Non-energy goods and sectors,

$ei2$ Energy goods and sectors other than coal, i.e., {OIL, PGN, ETR, EDS,

GAS},

$ni2$: Non-energy goods and sectors including coal,

el: Electricity goods and sectors, i.e., {PGN, ETR, EDS},

nl: Non-electricity goods and sectors, and

h: Factors, i.e., {CAP and LAB}.

Endogenous variables

X_i^p: Quantity of private consumption of the i-th good,

X^{pEn}, p^{xpEn}: Quantity and price of private consumption of the energy composite,

$F_{h,j}$, $p_{h,j}^f$: Quantity of the h-th factor employed by the j-th sector and the h-th factor price,

$X_{i,j}$: Quantity of the i-th intermediate good used by the j-th sector,

X_j^{En}, p_j^{pEn}: Quantity of the intermediate energy composite used by the j-th sector and its price,

Y_j, p_j^y: Quantity of value added produced by the j-th sector and its price,

Z_j, p_j^z: Quantity and price of the j-th gross output,

E_i, p_i^e: Quantity of the i-th good export and its price in local currency terms,

M_i, p_i^m: Quantity of the i-th good import and its price in local currency terms,

Q_i, p_i^q: Quantity of the i-th Armington's composite good and its price,

D_i, p_i^d: Quantity of the i-th domestic good and its price,

ε: Exchange rate,

T_j: Amount of domestic production tax imposed on the j-th sector,

T^d: Amount of (lump-sum) direct tax,

T_i^m: Amount of import tariff imposed on the i-th imported good, and

S, S^g: Amount of private and government saving.

X_i^g: Quantity of government consumption of the i-th good,

X_i^v: Quantity of investment uses of the i-th good,

υ_j: Markup rates on the household electricity charge,

in Simulation 1: υ_{PGN} : endogenous,

υ_j : exogenous and equal to zero for all j's except PGN,

in Simulation 2: υ_j : exogenous and equal to zero for all j's

Exogenous variables

FF_h: Endowment of the h-th factor,

S^f: Amount of foreign saving in the US dollar terms,

p_{nl}^{Wm}, p_{nl}^{We}: Price of the non-electricity import and export in the US dollar terms,

and *variables with superscripts of zero*, which represent the initial values of the corresponding variables.

τ_j, τ_i^m: Rates of domestic production tax on the *j*-th sector and import tariffs on the *i*-th good, and