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Five Agents Model for Oligopolistic Firms of Product Differentiation within Multi-Country/Multi-Sector System

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Abstract

This paper argues determination of factor demands, price, wage rate, production and inventory investment under generalized Leontief cost function in the oligopoly market of product differentiation in interindustry economy that domestically unique firm supplies sector-product in competing with foreign firms via five agents; a) agent-C determines factor demands under cost minimization; b) agent-P decides sector price given the cost function via profit maximization; c) agent-W decides sector wage rate under the cost function via profit maximization, and finally d) agent-X and agent-INV decide production and inventory simultaneously so as to meet demand. The model has been tested against the time-series data of the manufacturing sector of the main countries within multi-country/multi-sector economies; then the model has been justified for the these countries.

Keywords: multi-country/ multi-sector system, market of product differentiation, profit maximization, production and inventory, effective demand curve

JEL classifications: D58, O53

1. Introduction

The interindustry analysis has been initiated by W. Leontief (1953). The second contribution was made by the use of the perfect competition model in M. Saito (1971) where there exist a lot of firms competing each other; yet, main drawback lies in zero profit, being inconsistent with the reality. Monopolistic competition, used frequently in CGE model[1], also allows zero profit. Since the last two models suppose zero profit, the present paper plans to develop model of imperfect competition accommodating positive/negative profit of the realism. An approximation to the reality is believed to be an oligopoly model of product differentiation[2] within multi-country/multi-sector system (hereafter MCMS system in abbreviation)[3] where the demand/supply gap in the market is adjusted by the firm's decision[4].

This paper presumes that the MCMS system has N world commodity markets in the

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[1] See, for example, H. Lofgren, R. L. Harris and S. Robinson (2002) for CGE. Also K. Kratena (2005) estimated price equation in monopolistic market by econometric method.

[2] Studies on oligopoly of product differentiation have long story both in microeconomics and in industrial organization typically using game theory including differential game.

[3] We have up to now less studies of oligopoly of product differentiation using input-output model owing to the unavailability of input-output tables of non-competitive import type. Main domestic input-output time series tables have been made in those of competitive import type; so that, in order to incorporate oligopoly into my system, one necessarily become to employ data of international input-output table (multi-country/multi-sector table). The main advantage of using input-output system is capable of depicting nationwide or worldwide economies via interrelationship among sectors.

[4] Global/domestic supply chain management (SCM) assures the task.

world economy (N: number of commodities), each being interconnected by relative prices; and, individual commodity market has segment by its national border. As a result, the MCMS system has N commodity markets, each having K segmental markets separated by national border (K: number of countries). Then domestically unique firm (hereafter DUF in abbreviation) of the j^{th} sector of the k^{th} country is supposed to supply commodity for segmental domestic/external markets[5]; i.e., $N \times K$ intermediate plus final goods markets.

Table 1 Flow of i^{th} Product to Segmental Oligopolistic Market

	segment market 1	segment market 2	...	segment market K
1^{st} DUF	$\tilde{x}_i^{11}, cp_i^{11}, cg_i^{11}, ifp_i^{11}, inv_i^{11}$	$\tilde{x}_i^{12}, cp_i^{12}, cg_i^{12}, ifp_i^{12}, inv_i^{12}$	...	$\tilde{x}_i^{1K}, cp_i^{1K}, cg_i^{1K}, ifp_i^{1K}, inv_i^{1K}$
2^{nd} DUF	$\tilde{x}_i^{21}, cp_i^{21}, cg_i^{21}, ifp_i^{21}, inv_i^{21}$	$\tilde{x}_i^{22}, cp_i^{22}, cg_i^{22}, ifp_i^{22}, inv_i^{22}$	...	$\tilde{x}_i^{2K}, cp_i^{2K}, cg_i^{2K}, ifp_i^{2K}, inv_i^{2K}$
...	...	...	...	...
K^{th} DUF	$\tilde{x}_i^{K1}, cp_i^{K1}, cg_i^{K1}, ifp_i^{K1}, inv_i^{K1}$	$\tilde{x}_i^{K2}, cp_i^{K2}, cg_i^{K2}, ifp_i^{K2}, inv_i^{K2}$		$\tilde{x}_i^{KK}, cp_i^{KK}, cg_i^{KK}, ifp_i^{KK}, inv_i^{KK}$

note: $\tilde{x}_i^{hk} = \{x_{ij}^{hk} : j = 1,2,..,K\}$

Each segmental market is in imperfect competition of product differentiation with different prices. Then this paper is going to focus on the producer's behavior of the k^{th} segmental market of the j^{th} commodity. The comprehensive MCMS time series data of Project WIOD (World Input Output Database), the University of Groningen (Netherlands), endorses market competition among the domestic and the foreign firms; i.e., for the aggregated manufacturing sector, for example, the Japanese DUF has 88.3964061% share of total domestic transaction, the US's 63.919872%, Chinese 83.8942263%, Korean 59.1855156%, German 36.8229958%, French 54.6278056%, and English 33.2987367% at 2009; the aggregated manufacturing markets in the three European countries and Korea unveil highly competitive.

Now this paper intends to argue producer's behavior of determining factor demands, sector price, sector wage rate, inventory investment and sector production on the basis of so-called cost function of interindustry economy. On describing behavioral equations, micro-based modeling implies to elucidate the followings; a) who is decision maker; b) what is objective function to be optimized by the decision maker; c) what kind of variable is determined by the optimization; d) what kind of optimization method is utilized, being crucial for the argument. In line with this, the paper considers five collaborative agents within the DUF which are maximizing profits in determining price, wage rate, inventory investment and production individually under optimized factor demands. And, in estimating parameters of behavior equations, the paper utilize multi-period data in place of single period data as CGE model builders often use in the name of calibration. In realizing the above discussion, the cost function plays an important roll; up to now numbers of cost functions have been proposed. Among them the generalized Leontief cost function by M. Fuss (1977) would be appropriate for my analysis.

The section two explains the five agents model of producers behaviors on the relevant

[5] M. J. Melitz (2003) has argued international trade in decomposing DUF into the two; the first is the exporting firm dealing with both international and domestic transactions, and the other is the internal firm with only domestic one. The original idea might go back to W. Leontief and S. Strout (1963) in their interregional input-output model.

key variables, the section three investigates the validity of the model in the use of data of multi-country/multi-sector system and finally we concludes.

2. Producer's Oligopolistic Behaviour in the Firms of Product Differentiation

2.1 Market of Interindustry Economy and Five Agents Model of the Firms

When one face with market, first one should distinguish the market is in equilibrium or in disequilibrium; this paper assumes market is in equilibrium. If the jth segmental market of the kth country is in excess-demand ($X_j^{kD} > X_j^{kS}$; X_j^{kD} : demand ; X_j^{kS} : supply), the price will adjust demand partly, and demand will be cut off sometimes. Inversely, if the market is in excess-supply ($X_j^{kD} < X_j^{kS}$), producer will decrease production to meet demand. In both cases, unplanned inventory works for absorbing the demand/supply gap in collaboration with production. The above adjusting scheme is on production to stock in manufacturing sector. Ordered production in manufacturing sector always meets demand. Service industry differs; it seems to be ordered production because of no capability of inventory; e.g. banking service makes service in response to customers' requests.

The paper focuses on producer's behavior; determinations of factor demands, price, wage rate, production and inventory investment are under consideration. Then, assign cost function for determining factor demand; next, assign profit maximization for determining the other variables. It would be possible to assume monopolistic firms; yet, this paper supposes the DUF in the oligopoly market of product differentiation to avoid zero-profit.

The paper posts behaviors of producer; i.e. it describes factor demands, price, wage rate, production and inventory investment under profit maximization. First, set long-term cost function having capital stock inside, then goes to factor demands. Now it is essential to connect cost function with profit maximization; in this sense, the paper is in the same line with W. E. Diewert and K. J. Fox (2008), also early version W. E. Diewert and K. J. Fox (2004)[6]. They take monopolistic firms; instead, the paper takes oligopolistic firms of product differentiation.

Now consider the profit of j^{th} sector of k^{th} country, and develop Bertrand competition with price/wage rate as instruments. Demand X_j^{kD} and supply X_j^{kS} are clearly distinguished. The paper supposes to have five agents inside of the DUF; they cooperate each other leading to production behaviors. Upper agents (agent-P, agent-W, agent-X and agent-INV) plan to determine price, wage rate, production and inventory investment respectively under profit maximizations; on the other hand, lower agent (agent-C) seeks to cost minimization under restriction of production function, the behavior being consistent with profit maximizations. First the paper explains cost minimizing behavior.

2.2 Agent-C of Determining Factor Demands

Given set of prices and order of production X_j^{kS} , agent-C determines factor demands under the cost function:[7]

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6 W. E. Diewert and K.J. Fox (2008) model multi-sector system on the process of calculating technical progress.

7 The j^{th} sector of k^{th} country has production plant only in k^{th} country; then it has unique cost function. The subsidiary company's plant abroad located in l^{th} country $(l \neq k)$ by j^{th} sector of k^{th} country is incorporated into l^{th} country's cost function. And, when fulltime and non-fulltime workers co-exist, the term $\left(w_{j1}^k L_{j1}^k + w_{j2}^k L_{j2}^k\right)$ is used in (2.1) in its place of $w_j^k L_j^k$ where the subscript 1 stands for fulltime and the subscript 2 for non-fulltime.

$$C_j^k(X_j^{kS}, \widetilde{p}^k, w_j^k, r^k, t) = \min_{\widetilde{x}_j^k, L_j^k, K_j^k} \left(\sum_{h=1}^{K} \sum_{i=1}^{N} p_{ij}^{hk} x_{ij}^{hk} + w_j^k L_j^k + r^k K_j^k \right) \; j = 1,.., N \tag{2.1}$$

where variables are expressed in real term of local currency.

C_j^k: cost function ot j[th] sector of k[th] country

$\widetilde{x}_j^k = \{x_{ij}^{hk}; h = 1,2,.., K; i = 1,2,.., N\}$

x_{ij}^{hk}: input of i[th] product of h[th] country in j[th] sector production of k[th] country

L_j^k: labor input of j[th] sector of k[th] country

p_i^{hk}: price of i[th] product of h[th] country for k[th] country's production

$p_{ij}^{hk} = p_i^{hk} (j = 1,2,.., N)$

$\widetilde{p}^k = \{p_i^{hk}; h = 1,.., K; i = 1,.., N\}$

w_j^k: wage rate of j[th] sector of k[th] country

r^k: capital cost of k[th] country

On the mathematical form of (2.1), numbers of cost functions are posed so far. On account of no special kind of behavior in cost function, L. R. Christensen, D. W. Jorgenson and L. J. Lau (1973) have proposed translog cost function based on Taylor series expansion; nowadays the function has been widely used. However, cost function should have economic rationale; thus, the generalized Leontief cost function by M. Fuss (1977) would be notable by the reason why the cost function is a generalization from Leontief constant input coefficient. The mathematical specification of the cost function is $C(y, p, t) = \sum_{i,j} h_{ij}(y,t)\sqrt{p_i}\sqrt{p_j}$ (p_i: i-th facor price, y: production, $h_{ij}(y,t)$: symmetric and concave). As M. Fuss (1977) did not specify $h_{ij}(y,t)$, numbers of mathematical forms have been proposed later.

As this paper intends to investigate the interindustry economy for the past years, it take long-term cost function in which capital adjustment are accomplished within the period; however, it might be possible to introduce capital adjustment process like R. S. Pindyck and J. J. Rotemberg (1983)[8].

Now the paper employs W. E. Diewert and T. J. Wales (1987) generalized Leontief cost function.(see Appendix 1)[9] Then the use of Shephard's Lemma yields optimal intermediate, labor and capital demands. The factor demand equations employed here in share form are the followings:

$$\frac{x_{ij}^{hk}}{X_j^k} = \sum_{h1=1}^{K} b_{i1,j}^{h1,k} \sqrt{\frac{p_i^{h1,k}}{p_i^{hk}}} + b_{XX}\beta_i^{hk} X_j^k + b_{it}^{hk} t + b_{ip}^{hk} p_i^{k(e)} \tag{2.2}$$

where $p_j^{k(e)}$ is expectation of p_j^k. Equation (2.2) depicts bilateral intra-industry trade between h[th] and k[th] countries[10]. In equation (2.2), if $i1=i$ and $h1=h$, the first term in righthand side implies W. Isard's (1951) input coefficient (b_{ij}^{hk}) which is constant over time, but, otherwise, relative price $\sqrt{p_i^{h1,k}/p_i^{hk}}$ remains effective; the second term expresses scale economy; the third term Hick's neutral technical progress; the fourth term process innovation. Note that the cost function becomes known indirectly via estimated coefficients of factor demands, which is implemented on $X_j^{kS} = X_j^{kD} = X_j^k$; the corresponding marginal

[8] Cost function having all the optimal levels of factor demands are realized within a period is called long-term cost function; the equilibrium is in Full Static Equilibrium. Cost function having fixed inputs left inside as parameters is a short-term cost function, and is called restricted cost function; the equilibrium is in Partial Static Equilibrium. Cost function having fixed inputs partially realized is also a short-term; but, the equilibrium is in Partial Dynamic Equilibrium. R.S. Pindyck and J.J. Rotemberg (1983) is in the third case.

[9] The other possibilities are: e.g., E. Berndt and M.S. Kahled (1979) and S. Nakamura (2001).

[10] The trade is intra-industry trade of imperfect competition on intermediate goods.

cost also becomes known. The costs are described by the cost function; but, quadratic loss type of cost are not taken into accounts in the cost function as was first discussed in C.H. Holt, F. Modighiani, J.F. Muth and H.A. Simon (1960) (hereafter HMMS in abbreviation).

2.3 Agent-P of Determining Price

The DUF faces competition with the foreign rivalry firms. Cost function becomes known once factor demands are estimated; then, the corresponding marginal cost also becomes known theoretically and numerically. The price made by the DUF is calculated from marginal cost via profit maximization if demand curve is given; but unfortunately, calculated DUF's price does not coincide with the actual price[11]. This implies actual price could not be reduced from calculated theoretical DUF's price via profit maximization; therefore, to interpret the actual price, it is needed to introduce another scheme to profit maximization. T. Shibata and H. Kosaka (2013) have introduced conjectural variation by Frisch into profit maximization in the Japanese nine multi-region/multi-sector model.[12]

Alternatively this paper proposes another scheme of dynamic price formation also in profit maximization. Now profit maximization is stated: $\max_{p_j^k} \pi_j^{k(p)} = \max_{p_j^k} \{p_j^k X_j^{kD} - C_j^k\}$ in which X_j^{kD} stands for "perceived demand function" in the Negishi's sense (see T. Negishi (1961)); so that, the Negishi's subjective demand function is to be attached to profit maximization calculation.

Profit maximization problem in firms resembles optimal stabilization policy by government; i.e., profit corresponds to social welfare function while price to policy instrument. Early in the 50s, Phillips proposed three kinds of policy response functions in a macro-stabilization within multiplier-acceleration model, i.e. proportionate, derivative and integral policies; social welfare function, another pair of policy response function, also possesses the three kinds.[13] An analogous meaning of Phillips' is to introduce quadratic loss of price in addition to profit in our optimization problem; so that, maximizing (unit) profit plus quadratic loss of price would determine price in dynamism. Why does DUF consider price change apart from profit itself? Price, being derived by profit maximization, may have large fluctuation occasionally[14]; inversely, the restricted price may damage optimality of profit maximization. Unfortunately, society could accept no drastic change of price. Eventually, the DUF ought to face severe eye of society, and avoids drastic change of price; this is considered a kind of social cost that the DUF must have. It should be noted, at the same time, that the DUF could control price imperfectly; it is affected by social, political, ecological, and even demographic factors besides economic one.

Now consider price setting behavior unfavorable to drastic change of price; price change from the past is measured by $\left(p_j^k - p_{j,-1}^k\right)$; then, the quadratic loss of price of difference

[11] The DUF's price, which has been calculated from coefficients of both demand curve and cost function, is compared with the actual price.

[12] Conjectural variation is usually introduced to price change of rival firm in response to that of the current firm; but, T. Shibata and H. Kosaka (2013) have introduced conjectural variation into inventory change in response to price change within the DUF.

[13] Among them, integral policy is close to mine; it has social welfare function in discrete case $f = w(Y - Y^*)^2 + (G - G_{-1})^2$ (Y:endogenous; G:instrument), and has corresponding policy response function $G - G_{-1} = -w_i(Y - Y^*)\partial Y/\partial G$. See, for detail, S. J. Turnovsky (1977).

[14] Early in the 70s, G. C. Chow (1973) has stressed the same issue in optimal control as "instrument instability." And N. G. Mankiw (1985) has argued downward rigidity of price.

is expressed as a quadratic loss $\left(p_j^k - p_{j,-1}^k - \tilde{c}_j^{kp}\right)^2 (\tilde{c}_j^{kp} \neq 0)$ in general. Furthermore it would be plausible, in practical estimation, to relax strict difference to $(p_j^k - c_j^{kp2} p_{j,-1}^k - \tilde{c}_j^{kp})^2 (c_j^{kp2} > 0)$. Then profit maximization with quadratic loss of price is re-stated:

$$\max_{p_j^k} \tilde{\pi}_j^{k(p)} = \max_{p_j^k} \left\{ -\frac{1}{2} c_j^{kp1} (p_j^k - c_j^{kp2} p_{j,-1}^k - \tilde{c}_j^{kp})^2 + \frac{1}{X_j^{k*}} \left(p_j^k X_j^{kD} - C_j^k\right) \right\}. \tag{2.3}$$

X_j^{k*}: normal level of production with assumption $\partial X_j^{k*} / \partial p_j^k = 0$

As profit is evaluated in nominal term, it is denominated by X_j^{k*} to meet price related variable in (2.3). Then the first order condition yields by assuming $\partial w_j^k / \partial p_j^k = 0$:

$$\frac{\partial \tilde{\pi}_j^{k(p)}}{\partial p_j^k} = -c_j^{kp1}\left(p_j^k - c_j^{kp2} p_{j,-1}^k - \tilde{c}_j^{kp}\right) + \frac{1}{X_j^{*k}} \left(p_j^k \frac{\partial X_j^{kD}}{\partial p_j^k} + X_j^{kD} - MC_j^k \frac{\partial X_j^{kS}}{\partial p_j^k} \right) = 0 \tag{2.4}$$

Re-arranging term of price gives us dynamic equation of price determination:

$$p_j^k = \tilde{c}_j^{kp} + c_j^{kp2} p_{j,-1}^k + \frac{1}{c_j^{kp1}} \times \left(\frac{1}{X_j^{k*}} \right) \times \left(X_j^{kD} + p_j^k \frac{\partial X_j^{kD}}{\partial p_j^k} - MC_j^k \frac{\partial X_j^{kS}}{\partial X_j^{kD}} \frac{\partial X_j^{kD}}{\partial p_j^k} \right) \tag{2.5}$$

On specifying X_j^{kD} in demand side, it would be preferable to formulate demand allocating wealth over multiple-goods; e.g. sophisticated demand model like Deaton and Muellbauer (1980) is applicable.[15] Yet, as is mentioned, the Negishi's perceived demand function is supposed to have $\partial X_j^{kD} / \partial p_j^k = -\beta_j^{kp} \times \left(X_j^{kD} / p_j^k\right) (0 \leq \beta_j^{kp} \leq 1)$ in elasticity form.[16] Besides, unit increase of demand may increase supply via price; then, it is supposed $\partial X_j^{kS} / \partial X_j^{kD} = \delta_j^{kp} p_j^k (\delta_j^{kp} > 0)$. The two relations are inserted into (2.5):

$$p_j^k = \tilde{c}_j^{kp} + c_j^{kp2} p_{j,-1}^k + \frac{1}{c_j^{kp1}} \times \left(\frac{1}{X_j^{k*}} \right) \times \left(X_j^{kD} - \beta_j^{kp} X_j^{kD} + \beta_j^{kp} \delta_j^{kp} MC_j^k X_j^{kD} \right) \tag{2.6}$$

Finally, by putting $X_j^{k*} = X_j^{kD}$ [17], dynamic price equation for estimation is obtained.

$$p_j^k = \tilde{c}_j^{kp} + \frac{1 - \beta_j^{kp}}{c_j^{kp1}} + c_j^{kp2} p_{j,-1}^k + \frac{\beta_j^{kp} \delta_j^{kp}}{c_j^{kp1}} MC_j^k \tag{2.7}$$

Anticipated price elasticity β_j^{kp} by the DUF affects price determination for two directions; the first term $\left(1 - \beta_j^{kp}\right) / c_j^{kp1}$ in (2.7) is interpreted as pressure for reducing price that the agent-P has to care; on the other hand, price change may urge supply change, which may give rise to additional cost $\beta_j^{kp} \delta_j^{kp} MC_j^k / c_j^{kp1}$, eventually leading price increase.

Now relaxed price difference is assumed to split into deterministic and stochastic parts:

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[15] See, e.g. I. Mongelli, F. Neuwahl and J. M. Rueda-Cantuche (2010).

[16] As X_t^{kD} is no actual demand, but is anticipated by the DUF, so that X_j^{kD} should be $X_j^{kD(S)}$ where $X_j^{kD(S)}$ is demand anticipated by supplier.

[17] It is possible to put $X_j^{k*} = X_{j,-1}^{kD}$, or to put $X_j^{k*} = (X_j^{kD} + X_{j,-1}^{kD})/2$.

$$\tilde{c}_j^{kp} = \mu_j^{kp} + u_j^{kp}. \quad u_j^{kp} \sim N\left(0, \left(\sigma_j^{kp}\right)^2\right) \tag{2.8}$$

Equation (2.7) is then converted to:

$$p_j^k = \frac{\left(c_j^{kp1}\mu_j^{pk} + 1 - \beta_j^{kp}\right)}{c_j^{kp1}} + c_j^{kp2} p_{j,-1}^k + \frac{\beta_j^{kp}\delta_j^{kp}}{c_j^{kp1}} MC_j^k + u_j^{kp}. \tag{2.9}$$

The firm's price, affected by various factors other than economic one, becomes stochastic. Unknown parameters $(c_j^{kp1}, c_j^{kp2}, \mu_j^{kp}, \beta_j^{kp}, \delta_j^{kp})$ are undetermined even if regression is applied to equation (2.9); but, if the two parameters are restricted, all parameters become known.

From (2.7) or (2.9), increase of marginal cost gives rise to increase of price; secondly increase of scale economy $SE_j \left(SE_j^k = AC_j^k / MC_j^k\right)$ decreases price.

2.4 Agent-W of Determining Wage Rate

In the next, proceed to wage rate determination. Labor market is said to have two kinds, i.e. external and internal labor markets.[18] P. Doeringer and M. Piore(1971) is said to have first advocated internal labor market; for the MCMS system, labor demand L_j^k and wage rate w_j^k of the jth sector of kth country are resultants of behaviors of the firm's internal labor market; hence the DUF decides wage rate.[19]

Wage is cost of living for workers of the firm[20]; it is decided under the affect of constant level of wage rate (maybe minimum level of wage), and in proportion to the consumer price. These two factors are evaluated in the quadratic losses in seeking the objective:

$$-\frac{1}{2} c_j^{kw1} (w_j^k - c_j^{kw2} p_c^k - \tilde{c}_j^{kw})^2 \ ^{21} \tag{2.10}$$

$\tilde{c}_j^{kw}$: constant level of wage rate $\quad p_c^k$: consumer price

Consumer pice index is defined below:

$$p_c^k = \sum_{l=1}^{N} \theta_l^{k,cp} p_l^k \tag{2.11}$$

$\overline{cp}_l^{k,H}$: household expenditure of lth goods at base year

$$\theta_l^{k,cp} = \frac{\overline{cp}_l^{k,H}}{\overline{cp}^{k,HT}} \qquad \overline{cp}^{k,HT} = \sum_{l=1}^{N} \overline{cp}_l^{k,H}$$

Another determinant of wage rate is labor productivity which might come from "profit share" by M. L. Weitzman (1985)[22]; this is done by the connection to profit maximization. Therefore, wage rate is to be determined by profit maximization of the agent-W having the following objective function which differs slightly from that of agent-P:

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[18] Argument of Phillips curve is focusing on external labor market; instead, this paper on internal labor market.

[19] Labor mobility within and across sectors/countries are assorted in this model, but are taken into no consideration explicitly.

[20] R. G. Lipsey (1960) might be the first to put cost of living index in explaining wage rate.

[21] Consumer price p_c^k can be replaced by its expectation $p_c^{k(e)}$.

[22] M.L. Weitzman (1985) mentioned the model not in an optimization.

$$\max_{w_j^k} \tilde{\pi}_j^{k(w)} = \max_{w_j^k} \left\{ -\frac{1}{2} c_j^{kw1} (w_j^k - c_j^{kw2} p_c^k - \tilde{c}_j^{kw})^2 + \frac{1}{X_j^{k*}} \left(p_j^k X_j^{k(D)} - C_j^k \right) \right\} \tag{2.12}$$

where balancing two terms forces to denominate profit by normal level of production X_j^{k*} again. Now solve profit maximization under conjectural variation of agent-W against agent-P $\partial p_j^k / \partial w_j^k = \lambda_j^k \, (\lambda_j^k \geq 0)$[23]. The following two kinds of schemes are argued.

a) Scheme 1

Both side logarithmic perceived demand curve in the Negishi's sense $\partial X_j^{k(D)} / \partial p_j^k = -\beta_j^{kw} \left(X_j^{k(D)} / p_j^k \right) (0 \leq \beta_j^{kw} \leq 1)$ plus $\partial X_j^{k*} / \partial w_j^k = 0$ are assumed.

$$\frac{\partial \tilde{\pi}_j^{k(w)}}{\partial w_j^k} = -c_j^{kw1} \left(w_j^k - c_j^{kw2} p_c^k - \tilde{c}_j^{kw} \right) + \frac{1}{X_j^{k*}} \frac{\partial p_j^k}{\partial w_j^k} \left(X_j^{k(D)} + p_j^k \frac{\partial X_j^{k(D)}}{\partial p_j^k} \right) - \frac{1}{X_j^{k*}} \frac{\partial C_j^k}{\partial w_j^k}$$

$$= -c_j^{kw1} \left(w_j^k - c_j^{kw2} p_c^k - \tilde{c}_j^{kw} \right) + \frac{\lambda_j^k}{X_j^{k*}} \left(X_j^{k(D)} - \beta_j^{kw} X_j^{k(D)} \right) - \frac{L_j^k}{X_j^{k*}} = 0 \tag{2.13}$$

As before, putting $X_j^{k*} = X_j^k$ yields:

$$w_j^k = \left(\tilde{c}_j^{kw} + \frac{\lambda_j^k}{c_j^{kw1}} \left(1 - \beta_j^{kw} \right) \right) + c_j^{kw2} p_c^k - \frac{1}{c_j^{kw1}} \frac{1}{\left(X_j^k / L_j^k \right)} \tag{2.14}$$

Note that the constant term in (2.14) has the condition $\left(\tilde{c}_j^{kw} + \left(\lambda_j^k / c_j^{kw1} \right) \left(1 - \beta_j^{kw} \right) \right) \geq 0$; as a result, constant term zero implies $\tilde{c}_j^{kw} = \lambda_j^k = 0$.

b) Scheme 2

Alternatively the case of left hand side logarithmic demand curve $\partial X_j^{k(D)} / \partial p_j^k = -\beta_j^{kw} X_j^{k(D)}$ in the Negishi's sense plus $\partial X_j^{k*} / \partial w_j^k = 0$ is investigated in the next:

$$\frac{\partial \tilde{\pi}_j^{k(w)}}{\partial w_j^k} = -c_j^{kw1} \left(w_j^k - c_j^{kw2} p_c^k - \tilde{c}_j^{kw} \right) + \frac{1}{X_j^{k*}} \frac{\partial p_j^k}{\partial w_j^k} \left(X_j^{k(D)} + p_j^k \frac{\partial X_j^{k(D)}}{\partial p_j^k} \right) - \frac{1}{X_j^{k*}} \frac{\partial C_j^k}{\partial w_j^k}$$

$$= -c_j^{kw1} \left(w_j^k - c_j^{kw2} p_c^k - \tilde{c}_j^{kw} \right) + \frac{\lambda_j^k}{X_j^{k*}} \left(X_j^{k(D)} - \beta_j^{kw} p_j^k X_j^{k(D)} \right) - \frac{1}{X_j^{k*}} L_j^k \tag{2.15}$$

Consequently wage rate is determined:

$$w_j^k = \tilde{c}_j^{kw} + c_j^{kw2} p_c^k + \frac{\lambda_j^k X_j^k}{c_j^{kw1} X_j^{k*}} \left(1 - \beta_j^{kw} p_j^k \right) - \frac{1}{c_j^{kw1}} \frac{1}{\left(X_j^{k*} / L_j^k \right)} \tag{2.16}$$

Under the assumption of $X_j^{k*} = X_j^k$, wage rate determination is modified to:

$$w_j^k = \left(\tilde{c}_j^{kw} + \frac{\lambda_j^k}{c_j^{kw1}} \right) + c_j^{kw2} p_c^k - \frac{\beta_j^{kw} \lambda_j^k}{c_j^{kw1}} p_j^k - \frac{1}{c_j^{kw1}} \frac{1}{\left(X_j^k / L_j^k \right)} \tag{2.17}$$

If the coefficient of the current price p_j^k in (2.17) has statistically significant negative sign, $\beta_j^{kw} \lambda_j^k > 0$ must be assured; at the same time, constant term never diminish by $\beta_j^{kw}, \lambda_j^k > 0$. Eventually wage rate is interpreted as dependent on; constant level of wage rate, consumer price, current price and labor productivity. Then, increase of constant level of wage rate, consumer price and labor productivity all increase wage rate. As sector wage rate is determined within internal labor market, unemployment of external labor market has no effect on wage rate in both (2.14) and (2.17).

[23] Condition $\partial p_c^k / \partial p_j^k \approx 0$ is satisfied.

2.5 Agent-X/Agent-INV of Determining Production/Inventory

Analysis on inventory investment has been first arisen from morphology and chronology which has been started by Abramowits of NBER (see e.g. recent work by R. E. Carpenter and D. Levy (1998) of spectrum analysis of this type), and from model analysis. Model analysis has two kind of arguments; macro-analysis based on stock adjustment and micro-analysis on cost of production/inventory. HMMS (1960) would be the first to introduce costs relating to production/inventory behaviors. G.L. Childs (1967) has extended their model; after G.L. Childs, G.A. Hay (1970) and L. J. Maccini (1976, 1984) have extended objective function from cost to profit so as to endogenize price besides production/ inventory. M. S. Eichenbaum (1989) has classified relevant arguments into the two: i.e. production level smoothing and production cost smoothing. As this present paper introduces cost function into the arguments, the function is used to deduce multiple factor demands given production/inventory and bundle of factor prices; so that, like HMMS, quadratic losses of production and inventory are entered extended profit.

The paper assumes the DUF copes with meeting demand by mainly inventory, viz., unplanned inventory investment in the face of volatile fluctuation of demand because production needs to have time.[24] When part of demand is stochastic, the stochastic term is transferred to unplanned inventory investment. In the history of inventory research, a few attentions seem to be paid on unplanned inventory investment.[25] Usually unplanned inventory investment is interpreted as unanticipated excess sales or unanticipated unsold goods. (see, e.g. M. Lovell (1961, 1962)) When planned inventory model is applied to the actual data by regression, regression residual is left unexplained; unexplained residual may have valuable information of adjusting demand/supply nexus in the market. Unfortunately regression residual can not be explained by linear combinations of explanatory variables because two surfaces of explanatory variables and disturbance are orthogonal in vector space. This paper regards unplanned inventory investment as stochastic. Since planned inventory investment may have positive numerical values, its negative values evidences the existence of unplanned inventory investment. Now the countries having positive inventory investment of finished goods in the manufacturing sector for the total sample in the WIOD data are limited: only AUT, CHN, IND and MEX out of forty countries.[26] So that, the countries less the four would have unplanned inventory investment; even the four would also have possibility of having unplanned inventory investment. In macro-economics, Adelmans has reviewd R. Frisch random shock theory; following them, leading econometricians have confirmed Adelmans' experiment in the use of large scale econometric models (see B. Hickman(1970)). Since then, stochastic element play an important roll in

[24] F. Modighiani (1957) has referred to four business reasons for holding inventory; a) cost of supplying raw material on economy of scale in ordering lot; b) maintaining inventory of finished goods to smooth production due to cost of production change; c) price speculation for finished goods and raw materials for anticipated future price increase; d) uncertainty of demand and time needed for production in finished goods; then the fourth reason is important.

[25] The Klein's III model (see L.R. Klein (1950)) was composed of twelve behavioral equations and four definitions; unplanned inventory investment was viewed as stochastic in the residual of inventory investment equation.

[26] It should be noticed to distinguish inventory of finished goods, that of raw materials and that in process. Inventory investment of j^{th} finished goods of k^{th} country in MCMS system is inv_j^{kk} ; that of raw material is contained in $inv_i^{hk}\ (i \neq j)$ together with others; that in process is ignored. Now the inventory investment of finished goods is argued here. See Appendix 2 for country code.

macro-model; e.g. RBC, time series analysis and DSGE model. Stochastic cyclical properties of unplanned inventory investment also must be analyzed.

As is noted, modality of production has two kinds: i.e. manufacture and service productions. Furthermore manufacture has the two types, i.e. production to stock and order production[27]; distinction between the two is that production starts after order in the latter and starts anticipating sales in the former. Service industry becomes order production because of no capability of inventory of finished products[28]; hence, production for service will be made after request of service. In the WIOD data, all countries have non-zero finished inventory investment for the total sample in the manufacturing sector. Therefore inventory issue concerns mainly with production to stock of manufacturing sectors where inventory is still issuable to be solved together with production.

Next, explain model of mitigating schemes of demand/supply gap in interindustry economy. Price has function of adjusting the gap in a small portion because it is determined by profit maximization in the above model; therefor, the issue of adjusting the gap is solved mainly by production/inventory behaviour. The DUF stocks finished products in seeking for the planned level of inventory investment in the first stage; meanwhile, the firm copes with sudden request of shipment by unplanned inventory investment in collaboration with production. In service industry with incapability of inventory, production solely fulfills the important task.

a) Deterministic Planned Inventory Investment
Inventory of Finished Goods

A model of inventory investment of finished goods by M. Lovell (1961, 1962) is composed of four assumptions; i.e., equilibrium or desired level of inventory investment, planned and actual ones, and anticipation of demand.

Assumption L1: equilibrium (or desired) inventory investment

$$inv^e = \alpha + \beta X^D \qquad X^D\text{: shipment} \tag{2.18}$$

Assumption L2: planned inventory investment
He has posed two alternatives of planned inventory:

$$inv^p = \alpha + \beta \hat{X}^D \tag{2.19}$$

$$inv^p = \delta inv^e + (1-\delta)\, inv_{-1} \tag{2.20}$$

Assumption L3: actual inventory investment
Planned and unplanned inventories are clearly distinguished; by the distinction, unplanned inventory becomes known as stochastic in the model.

$$inv = inv^p + \left(\hat{X}^D - X^D\right) = inv^p + inv^{up} \tag{2.21}$$

[27] Typical examples of order production are, e.g., aircraft and heavy industries with features of long production period and of inventory in production process.
[28] It has exceptions like wholesale; i.e., service industry of manufacture-dependence has inventory of raw material sent by manufactures.

Gap of sales anticipation from the actual value makes unplanned inventory in equation (2.21).
Assumption L4: prediction of demand

$$\hat{X}^D = \rho X_{-1}^D + (1-\rho) X^D \tag{2.22}$$

The present paper argues the j^th sector of the k^th country in interindustry economy. In general, demand flow of i^th product of h^th country other than the inventory investment is defined as shipment:

$$X_i^{hD0} = \sum_{j=1}^{N}\sum_{k=1}^{K} x_{ij}^{hk} + \sum_{k=1}^{K} cph_i^{hk} + \sum_{k=1}^{K} cpn_i^{hk} + \sum_{k=1}^{K} cg_i^{hk} + \sum_{k=1}^{K} if_i^{hk} \tag{2.23}$$

x_{ij}^{hk} : input of i^th product of h^th country in j^th sector production of k^th country
cph_i^{hk} : household consumption of i^th product of h^th country in k^th country
cpn_i^{hk} : non-household consumption of i^th product of h^th country in k^th country
cg_i^{hk} : government expenditure of i^th product of h^th country in k^th country
if_i^{hk} : fixed investment of i^th product of h^th country in k^th country

As this paper is in the same line with M. Lovell (1961,1962), planned inventory investment, employing Assumption L2, is:

$$inv_j^{kkp} = c_j^{kh0} + c_j^{kh2} X_j^{kD0}$$ (2.24)[29]

Operational fund for inventory may be needed in production management of the most firms; then the bank loan affects inventory holding like $c_j^{kh0} = c_j^{kh3} - c_j^{kh4} rs^k$ (rs^k : short-term interest rate); another case of price speculation would have $c_j^{kh0} = c_j^{kh3} + c_j^{kh4} p_j^{k(e)}$ ($p_j^{k(e)}$: expected price).

b) Determining Production and Stochastic Unplanned Inventory Investment

Agent-X is watching market so as to decide X_j^{kS} with a view to X_j^{kD0} in collaboration with agent-INV, finally resulting in $X_j^{kS} = X_j^{kD}$ [30]; hence, market clearance is made by firm's decision, not by market price. Price in the model is devoted to profit maximization seeking for smoothness of its fluctuation, not devoted to adjust demand/supply gap.

Costs are needed in adjusting supply to demand. HMMS have argued these costs. They have considered short-term decisions; so that, they disregarded capital stock and also price adjustment. First, labor adjustment in production is to increase/decrease labors under certain level of production rate; regular payroll cost is usual and hiring and layoff cost is additional. Second, production rate adjustment says overtime is to raise level of production rate, and idle-time to reduce the level; as a result, both have additional costs, i.e. overtime cost and backlog cost respectively. Third, they raise inventory adjustment. These additional costs are represented in quadratic loss. They estimated on labor adjustment; regular payroll amounts to 643.1, and hiring and layoff to 8.2; on production rate adjustment, overtime cost to 42.0, and back order to 166.9; finally inventory adjustment to 139.8.[31] Their estimate

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[29] Another formulation of planned inventory investment is posed in the place of (2.24) as $inv_j^{kkp} = c_j^{kh0} + c_j^{kh2}\sqrt{X_j^{kD0}}$.
[30] Demand-supply relation $X_j^{kS} = X_j^{kD0} + inv_j^{kk} + \sum_{h\neq k} inv_j^{hk}$ is assured.
[31] See page 24 of HMMS(1960)

implies regular labor cost has large portion; inventory cost unexpectedly has high numerical value. Following them, this paper considers unplanned inventory investment assumes to cost in quadratic loss; and, assigns the cost function to the two production related costs by reasons firstly that these costs are negligible in their estimate, and secondly that cost function incorporating non-linear elements stirs new issue of constructing cost function. After HMMS (1960), G. L. Childs (1967) and G. A. Hay (1970) also took quadratic loss of inventory. Now this paper supposes agent-INV is in act so as to maximize profit. Yet, unlike them, this paper will take loss of inventory investment in its place of inventory stock besides profit:[32]

$$\tilde{\pi}_j^{k(INV)} = -\frac{1}{2} c_j^{kh1} \left(inv_j^{kk} - inv_j^{kkp} \right)^2 + \frac{1}{p_j^{k*}} \left(p_j^k X_j^{kD} - C_j^k \right) \tag{2.25}$$

where normal price p_j^{k*} intends to transform nominal profit to real term in order to balance inventory investment.

Case where $\partial X_j^{kS} / \partial inv_j^{kk} = 0$

Under $\partial X_j^{kS} / \partial inv_j^{kk} = \partial p_j^k / \partial inv_j^{kk} = \partial p_j^{k*} / \partial inv_j^{kk} = 0$, the agent-INV optimizes $\tilde{\pi}_j^{k(INV)}$ with respect to inv_j^{kk}:

$$\frac{\partial \tilde{\pi}_j^{k(INV)}}{\partial inv_j^{kk}} = -c_j^{kh1} \left(inv_j^{kk} - inv_j^{kkp} \right) + \frac{p_j^k}{p_j^{k*}} = 0 \tag{2.26}$$

The first order condition yields deterministic level of optimal inventory investment; deviation form the actual one is made up by stochastic unplanned inventory investment inv_j^{kkup} on $p_j^{k*} = p_j^k$.

$$inv_j^{kk} = inv_j^{kkp} + + inv_j^{kkup} = \left(1 / c_j^{kh1} + c_j^{kh0} \right) + c_j^{kh2} X_j^{kD0} + u_j^{kI} . \tag{2.27}$$

u_j^{kI}: Gaussian stationary process

The agent-INV keeps monitoring shipment X_j^{kD0} ; it judges instantaneously whether inventory or production should cope with shipment. The action of the agent-INV coping with unusual and exceptional (i.e., mathematically random) fluctuation of shipment will lead to unplanned inventory investment. Inventory instantaneously could respond to random fluctuation, which has been pointed out by F. Modighiani (1957) as fourth reason of holding inventory.

Now, on the other hand, behavior of Agent-X on production will undertake the rest of the task of shipment to meet production to total demand:[33]

$$X_j^{kS} = X_j^{kD} = X_j^{kD0} + inv_j^{kk} = X_j^{kD0} + \left(1 / c_j^{kh1} + c_j^{kh0} + c_j^{kh2} X_j^{kD0} + u_j^{kI} \right)$$

$$= \left(1 / c_j^{kh1} + c_j^{kh0} \right) + \left(1 + c_j^{kh2} \right) X_j^{kD0} + u_j^{kI} \qquad 1 + c_j^{kh2} > 1 \tag{2.28}$$

[32] M.S. Eichenbaum (1989) takes into accounts of the costs relating to inventory stock H_j as in $C_{It} = (b/2)\left(X_j^D - cH_j\right)^2 + e_{1t} H_j + (e_2/2) H_j^2$:i.e., the first term is traditional cost deviating from desired level of inventory, and the last two are the inventory holding cost by A.S. Blinder (1986).

[33] Equations (2.27) and (2.28) are, therefore, dependent.

Hence variability of X_j^{kS} is over that of X_j^{kD0}. In sectors with no inventory such as in most service ones, production undertakes solely all the task.

Next the disturbance term u_j^{kI} is assumed to obey first to third order auto-regressive process with zero mean:

$$u_j^{kI} = \rho_{j1}^{kI} u_{j,-1}^{kI} + \varepsilon_j^{kI} \qquad \varepsilon_j^k \sim i.i.d.N\left(0, \left(\sigma_j^{kI}\right)^2\right) \tag{2.29a}$$

$$u_j^{kI} = \rho_{j1}^{kI} u_{j,-1}^{kI} + \rho_{j2}^{kI} u_{j,-2}^{kI} + \varepsilon_j^{kI} \qquad \varepsilon_j^k \sim i.i.d.N\left(0, \left(\sigma_j^{kI}\right)^2\right) \tag{2.29b}$$

$$u_j^{kI} = \rho_{j1}^{kI} u_{j,-1}^{kI} + \rho_{j2}^{kI} u_{j,-2}^{kI} + \rho_{j3}^{kI} u_{j,-3}^{kI} + \varepsilon_j^{kI} \qquad \varepsilon_j^k \sim i.i.d.N\left(0, \left(\sigma_j^{kI}\right)^2\right) \tag{2.29c}$$

The most presumable case of second auto-regressive process (2.29b) would have positive ρ_{j1}^{kI} around unity, and negative ρ_{j2}^{kI} less than unity; so that, both condition $D = \left(\rho_{j1}^{kI}\right)^2 + 4\rho_{j2}^{kI} < 0$ (i.e., characteristic equation has complex roots) and absolute value of roots less than unity by $\sqrt{-\rho_{j2}^{kI}}$ would force the stochastic process obeys a weakly stationary processes.

Regression (2.27) has disturbance of zero-mean first to third order auto-regressive process in (2.29a)-(2.29c); in other word, regression of equation (2.27) is thought of as having disturbance term of function to adjust gap of demand/supply, so that it fluctuates in stochastic manner. By the regression, actual inventory investment data is split into deterministic planned and stochastic unplanned inventory investments. Unplanned inventory investment is disturbance term of regression which is orthogonal to projection surface; then, it is never represented by liner combination of X_j^{kD0}.

Case where $\partial X_j^{kS} / \partial inv_j^{kk} \neq 0$

The next case has partial linkage to profit. Yet, the case where agent-INV has conjectural variation to Agent-X as in $\partial X_j^{kS} / \partial inv_j^{kk} = \lambda_j^{kIX} \neq 0$ is shown to be connected fully with profit; so that, quadratic loss of inventory coupled with profit makes sense in relevant profit maximization argument. Now, if $\lambda_j^{kIX} > 0$, the agent-INV conjectures that an increase of planned inventory makes increase of production; on the other hand, if $\lambda_j^{kIX} < 0$, the agent-INV conjectures an increase of unplanned inventory caused by unsold goods makes decrease of production.

$$\frac{\partial \tilde{\pi}_j^{k(INV)}}{\partial inv_j^{kk}} = -c_j^{kh1}\left(inv_j^{kk} - inv_j^{kkp}\right) + \frac{1}{p_j^{k*}}\left(p_j^k \frac{\partial X_j^{kD}}{\partial inv_j^{kk}} - \frac{\partial C_j^k}{\partial X_j^{kS}} \frac{\partial X_j^{kS}}{\partial inv_j^{kk}}\right) = 0 \tag{2.30}$$

$$inv_j^{kk} = inv_j^{kkp} + 1/c_j^{kh1} - \frac{\lambda_j^{kIX}}{c_j^{kh1}} \frac{MC_j^k}{p_j^k} + u_j^{kI} = inv_j^{kkp} + 1/c_j^{kh1} - \frac{\lambda_j^{kIX}}{c_j^{kh1}} \frac{AC_j^k}{p_j^k SE_j^k} + u_j^{kI} \tag{2.31}$$

u_j^{kI} : stochastic unplanned inventory investment of auto-regressive process

The equation (2.31) implies behavior of decreasing inventory is occurred by an increase of marginal cost MC_j^k or average cost AC_j^k ; on the other hands, scale economy SE_j^k increases inventory. The third term of (2.31) is what has been stressed by M. S. Eichenbaum (1989) as production cost smoothing. In another case of $\partial p_j^k / \partial inv_j^{kk} = \lambda_j^{kIp} \neq 0$, meaningless result is obtained; therefore, agent-INV having conjectural variation to agent-P is unrealistic. Moreover the case $\partial w_j^k / \partial inv_j^{kk} = \lambda_j^{kIw} \neq 0$ may be worthwhile.

The corresponding equation of production decision is, by inserting (2.31):

$$X_j^{kS} = X_j^{kD} = X_j^{kD0} + inv_j^{kk} = X_j^{kD0} + \left(1/c_j^{kh1} + c_j^{kh0} + c_j^{kh2} X_j^{kD0} - \frac{\lambda_j^{kIX}}{c_j^{kh1}} \frac{MC_j^k}{p_j^k} + u_j^{kI} \right)$$

$$= \left(1/c_j^{kh1} + c_j^{kh0}\right) + \left(1 + c_j^{kh2}\right) X_j^{kD0} - \frac{\lambda_j^{kIX}}{c_j^{kh1}} \frac{MC_j^k}{p_j^k} + u_j^{kI}. \qquad 1 + c_j^{kh2} > 1 \tag{2.32}$$

c) Dynamic Production Decision under Reciprocal Conjectural Variations[34]

Alternative case where reciprocal conjectural variations between agent-X and agent-INV will be considered in the next. Now, the objective function of the agent-INV linked with profit is the same with (2.25).

Long-Run/Short-Run Strategy for Production

The agent-X is assumed to have strategy for production: i.e., long-run and short-run strategies. The long-run strategy is assumed: i.e., an increasing rate of production $\left(X_j^{kS} - X_{j,-1}^{kS}\right) / X_{j,-1}^{kS}$ is to be attained to the target b_j^{kx1}; so that, $\left(X_j^{kS} - (1 + b_j^{kx1}) X_{j,-1}^{kS}\right) = 0$ is seeked; quadratic loss $c_j^{kx1} (X_j^{kS} - c_j^{kx2} X_{j,-1}^{kS})^2$ $(c_j^{kx1} > 0)$ is taken into accounts in the objective function. The short-run strategy is assumed: i.e., difference of production is to be achieved to the target $X_j^{kS} - X_{j,-1}^{kS} = b_j^{kx2}$; quadratic loss $c_j^{kx1} (X_j^{kS} - X_{j,-1}^{kS} - b_j^{kx2})^2$ is taken into consideration. Hence the objective function of the agent-X to be maximized is:

$$\tilde{\pi}_j^{k(X)} = -\frac{1}{2} c_j^{kx1} (X_j^{kS} - c_j^{kx2} X_{j,-1}^{kS})^2 - \frac{1}{2} c_j^{kx1} (X_j^{kS} - X_{j,-1}^{kS} - b_j^{kx2})^2$$

$$+ \frac{1}{p_j^{k*}} \left(p_j^k X_j^{kD} - C_j^k\right) \tag{2.33}$$

with restriction $X_j^{kS} = X_j^{kD}$ where $\partial X_j^{kD} / \partial X_j^{kS} = 1$ is assumed.[35] M.S. Eichenbaum (1989) has stated production related cost is $C_X = v_t X_j^S + (a/2)(X_j^S)^2$; in our connection, this paper assign cost function to the first term of C_X, and the first term of (2.33) to the second term C_X of which he called as term embodying production level smoothing.

First, agent-INV optimizes objective function (2.25) with $\partial X_j^{kS} / \partial inv_j^{kk} = \lambda_j^{kIX} \neq 0$, yielding:

$$\frac{\partial \tilde{\pi}_j^{k(INV)}}{\partial inv_j^{kk}} = -c_j^{kh1} \left(inv_j^{kk} - inv_j^{kkp}\right) - \frac{1}{p_j^{k*}} \frac{\partial C_j^k}{\partial X_j^{kS}} \frac{\partial X_j^{kS}}{\partial inv_j^{kk}} = -c_j^{kh1} \left(inv_j^{kk} - inv_j^{kkp}\right) + 1 - \frac{\lambda_j^{IX}}{p_j^{k*}} MC_j^k = 0$$

$$inv_j^{kk} = inv_j^{kkp} + 1/c_j^{kh1} - \frac{\lambda_j^{kIX}}{c_j^{kh1}} \frac{MC_j^k}{p_j^k} + u_j^{kI} = inv_j^{kkp} + 1/c_j^{kh1} - \frac{\lambda_j^{kIX}}{c_j^{kh1}} \frac{MC_j^k}{p_j^k} + u_j^{kI}, \tag{2.34}$$

u_j^{kI} : stochastic unplanned production of auto-regressive process

which is the same in (2.31). In the second, agent-X optimizes (2.33) with :

[34] L. R. Klein (1950) and R. C. Fair (1994) have taken the dynamic decision of production in different ways from mine.

[35] Joint objective function $\tilde{\pi}_j^{k(INVX)} = -c_j^{kh1} / 2 \left(inv_j^{kk} - inv_j^{kkp}\right)^2 - c_j^{kx1} / 2 \left(X_j^{kS} - X_j^{kS(p)}\right) + 1/p_j^* \left(p_j^k X_j^{kD} - C_j^k\right)$ is also worthwhile to be investigated.

$\partial inv_j^{kk} / \partial X_j^{kS} = \lambda_j^{kXI}$:

$$\frac{\partial \tilde{\pi}_j^{k(X)}}{\partial X_j^{kS}} = -c_j^{kx1}\left(2X_j^{kS} - \left(c_j^{kx2}+1\right)X_{j,-1}^{kS} - b_j^{kx2}\right) + 1 - \frac{1}{p_j^k}\frac{\partial C_j^k}{\partial X_j^{kS}} = 0 \quad (2.35)$$

$$X_j^{kS} = \left(1/2c_j^{kx1} + b_j^{kx2}/2\right) + \frac{\left(c_j^{kx2}+1\right)}{2}X_{j,-1}^{kD} - \frac{1}{2c_j^{kx1}}\frac{MC_j^k}{p_j^k} + u_j^{kX} \quad (2.36)$$

u_j^{kX} : stochastic unplanned production (white noise)

Both equations (2.34) and (2.36) have common explanatory variable of marginal cost, which comes from the linkage to profit.

To sum up, producer's behaviors of determining intermediate demands, price, wage rate, production and inventory investment are endogenized for jth sector of kth country under profit maximization; as a result, total, marginal, and average costs plus scale economy are also endogenized. If final demand side models such as consumer expenditure, government expenditure and so on for jth sector of kth country are endogenized, it is become to know econometric model for jth sector of kth country. To enlarge individual sector to the whole sectors, one come to possess an econometric general equilibrium model for the whole national economy.

Now, to see empirical validity of the above formulated model, the paper select main countries' manufacturing sector in the next section.

3. Empirical Studies on the Proposed Model

3.1 World Input Output Database (WIOD)

The paper utilizes MCMS data of WIOD (World Input Output Database Project), University of Groningen (Netherlands).[36] The project has made historical world wide interindustry data covering 1995 to 2011; sector classification is thirty six for main forty countries.[37] The data has been converted in the following. First, extract data from the World Input-Output Tables in nominal dollar term, rearranging spreadsheet form to time series data; second, denominate it in local currency by exchange rate and price deflator of local currency, which are extracted from the Social Economic Accounts; then, obtain real intermediate and final demands in local currency. Finally, obtain local nominal value-added data from the National Input-Output Tables. A highlight is to employ profit maximization throughout from deriving equations of factor demands to those of the relevant key variables; as a result, total, marginal and average costs and scale economy are all calculated endogenously.

3.2 Estimated Results for Price/Wage Rate Equations

The table 2 shows estimated result of price equations of selected countries. In estimating price equation (2.9), one need to have marginal cost[38]; due to complexity of

[36] Homepage of WIOD Project is : http://www.wiod.org/

[37] For detail of sector classification and country code, see Appendix 2.

[38] Capital cost is omitted in calculating total cost (marginal cost also) because of its unreliability.

calculating the total cost functions, only limited number of countries are taken into consideration.

Table 2 Parameter Estimates of Price Equations for Selected Countries

$$p_j^k = \left(c_j^{kp1}\mu_j^{kp} + 1 - \beta_j^{kp}\right)/c_j^{kp1} + c_j^{kp2}p_{j,-1}^k + \left(\beta_j^{kp}\delta_j^k / c_j^{kp1}\right)MC_j^k$$

country	$cons\tan t$	$p_{j,-1}^k$	MC_j^k	$R(adj.)$
CHN	0.616803		0.427521	0.818071
FRA	0.827812		0.233921	0.819480
GBR	-0.196278	0.721143	0.889006	0.930864
IND			1.184481	0.864532
JPN	0.715313[1]		0.417345	0.462455
KOR	0.251982		1.875222	0.817940
NLD	0.287390[2]		2.236780	0.505565
RUS			1.650453	0.999374
TUR	0.347438		1.423923	0.999123

note 1: Dummy variable is attached besides constant term

note 2: Coefficient of dummy variable without constant term

For aggregated manufacturing sector (category 2 in Appendix 2), a pair of equations are estimated: the one is dynamic equation (2.9) and the other is static equation with $c_j^{kp2} = 0$ in (2.9), which leads to $p_t = d_0 + d_1 MC_t$. Between the two, the equation selected by the use of AIC criterion is tabulated in the Table 1; statistical significance of coefficients of marginal costs less than 5% are all satisfied; the zero constant term and the negative constant term with statistical significance less than 5% are both allowed. The individual parameters is unobtainable from the estimated parameters on account of identification problem of parameters. Observing that the selected equations are the latter static one in most countries may evidence the estimation results have close connection with interpolation by non-survey method for IO data making process. Let us now see the result in detail. Countries with coefficient of marginal cost greater than unity $\beta_j^{kp}\delta_j^k > c_j^{kp1}$ (i.e., IND, KOR, NLD, TUS and TUR) are considered to take more attention on profit maximization rather than price change. In contrary countries with the coefficient less than unity $\beta_j^{kp}\delta_j^k < c_j^{kp1}$ (i.e., CHN, FRA, GBR and JPN) have tendency to take more attention on price change rather than profit maximization; and, GBR has been adjusting price in dynamical way while the rest in static way.

Next, proceed to wage rate equation. The two alternative equations of (2.14) and (2.17) are investigated. The Table 3 shows estimated results of wage rate equations for all countries on aggregated manufacturing sector (category 2). The criterion of AIC is used for the best model after deleting variables having no proper sign and no statistical significance of less than 5%; then the selected equation between the two is tabulated.

Table 3 Parameter Estimates of Wage Rate Equations

Scheme 1: $w_j^k = \left(\tilde{c}_j^{kw} + \left(\lambda_j^k / c_j^{kw1}\right)\left(1-\beta_j^{kw}\right)\right) + c_j^{kw2} p_c^k - 1/c_j^{kw1}\left(X_j^k / L_j^k\right)$

Scheme 2: $w_j^k = \left(\tilde{c}_j^{kw} + \lambda_j^k / c_j^{kw1}\right) + c_j^{kw2} p_c^k - \left(\beta_j^{kw}\lambda_j^k / c_j^{kw1}\right)p_j^k - 1/c_j^{kw1}\left(X_j^k / L_j^k\right)$

country	*scheme*	*constant*	p_c^k	p_j^k	$1/\left(X_j^k / L_j^k\right)$	$R(adj.)$
AUS	scheme1	42.46939	39.33653		-8172.996	0.984123
AUT	scheme1		44.34505		-1510.371	0.987658
BEL	scheme1	12.33006	40.91571		-2941.908	0.986259
BGR	scheme2	0.050816[1]	0.204170	-0.061674		0.984923
BRA	scheme1		6.556129			0.900354
BRA	scheme1	112.8273			-16584.01	0.927523
CAN	scheme1	112.8273			-16584.01	0.927523
CYP	scheme1		13.22611			0.797113
CZE	scheme1		260.2769		-133404.2	0.977649
DEU	scheme1		51.12173		-1806.796	0.982747
DNK	scheme2	81.86407[1]	488.4785	-199.0169	-126302.7	0.995261
ESP	scheme1	4.478117	16.69856			0.954631
FIN	scheme1		41.93808		-1932.303	0.988589
FRA	scheme1		47.54022		-2634.938	0.991667
GBR	scheme1		40.54534		-1719.351	0.985426
GRC	scheme1		13.67843			0.793732
IDN	scheme1		6.413251		-120.2470	0.971016
IND	scheme2	70.22399	54.83656	-50.00616	-13043.76	0.958516
IRL	scheme2	49.42886	11.53600	-14.32071	-3893.344	0.989874
ITA	scheme1	1.797403	24.92825			0.990878
JPN	scheme1	5469.319			-17345988	0.911783
LTU	scheme1		22.18225		-859.3114	0.967565
LUX	scheme1	43.00112	11.73674		-3138.963	0.878883
LVA	scheme1		1.834740			0.925263
MEX	scheme2	91.81925	70.96765	-76.93247	-12817.75	0.978145
MLT	scheme1	20.41376			-547.1541	0.939196
NLD	scheme1		37.96813		-1207.947	0.994919
POL	scheme1		16.55211			0.909568
ROM	scheme2	0.720331[1]	3.616949	-3.615832		0.984088
RUS	scheme1		18.00503		-787.6038	0.989022
SWE	scheme1		406.5810		-172487.3	0.988370
USA	scheme1	31.60740	46.53065		-7841.654	0.992238

note 1: statistically insignificant

The notable is the two; a) the coefficient of labor productivity is statistically significant for almost all the countries, which unveils wage rate is determined in internal labor market, not in external labor market in interindustry level; b) the coefficient of the current price with statistical significance can be observed for several countries, which evidences that the different kinds of subjective demand functions are used for these countries. Countries with coefficient of labor productivity zero ($1/c_j^{kw1} \approx 0$) are considered to take more attention on cost of living in wage rate determination while those with coefficient of labor productivity non-zero ($1/c_j^{kw1} \neq 0$) on profit maximization; the table 4 shows categorized countries.

Table 4 Categorizing Countries by Wage Rate Determination

	$1/c_j^{kw1} \approx 0$	$1/c_j^{kw1} \neq 0$
Scheme 1	BRA,CYP,ESP,GRC,ITA, ITA,LVA,POL	AUS,AUT,BEL,BRA,CAN, CZE,DEU,FIN,FRA,GBR, IDN,JPN,LTU,LUX,MLT, NLD,RUS,SWE,USA
Scheme 2	BRG,ROM	DNK,IND,IRL,MEX

3.2 Estimated Results for Production Equations

Now the three kinds of production equations, viz., (2.28), (2.32) and (2.36) are considered. The estimated static equations (2.28) (labeled as Static 1 in the Table 5) with requirement of coefficient of shipment $1+c_j^{h2}>1$ are listed in the Table; second, those of the static equation (2.32) (labeled as Static 2) with requirements of coefficients of shipment $1+c_j^{h2}>1$ plus negative coefficient of real marginal cost are listed in the Table, allowing disturbance of non white noise; finally, those of dynamic equation (2.36) (labeled as Dynamic) with requirements of negative coefficient of real marginal cost plus coefficient of one period lagged production less than unity are listed. Some countries have plural candidates; best estimation is selected by the use of AIC by evening the sample length.

Table 5 Estimated Results of Production Equation

Static 1: $X_j^{kS} = \left(1/c_j^{kh1} + c_j^{kh0}\right) + \left(1 + c_j^{kh2}\right) X_j^{kD0} + u_j^{kI}$

Static 2: $X_j^{kS} = \left(1/c_j^{kh1} + c_j^{kh0}\right) + \left(1 + c_j^{kh2}\right) X_j^{kD0} - \left(\lambda_j^{kIX}/c_j^{kh1}\right) MC_j^k / p_j^k + u_j^{kI}$

Dynamic: $X_j^{kS} = \left(1/2c_j^{kx1} + b_j^{kx2}/2\right) + \left(\left(c_j^{kx2}+1\right)/2\right) X_{j,-1}^{kD} - \left(1/2c_j^{kx1}\right) MC_j^k / p_j^k + u_j^{kX}$

Equations	Country
Static 1	CHN,FRA,GBR,IND,JPN,KOR,RUS
Static 2	TUR
Dynamic	NLD

4. Concluding Remarks

Approach which this paper employed here is to set cost function first; secondly, to estimate intermediate demands, labor and capital demands; thirdly, to estimate indirectly cost function numerically from estimated factor demands; fourthly, to deduce marginal and average costs and scale economy endogenously; finally, to estimate wage rate and price determination equations, all under profit maximization. The proposed model could be called five agents model where the agents within the DUF cooperate each other in determining relevant key variables. From empirical investigation using data of the WIOD, the model is largely supported. Enlarging the individual sector to the nationwide and worldwide economies, and endogenizing final demands such as consumer expenditure and so on will be next research issues.

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Appendix 1: W.E.Diewert&T.J.Wales's Generalized Leontief Cost Function for MCMS System

W.E.Diewert and T.J.Wales (1987) has posed a generalized Leontief cost function for the domestic multi-sector system.

$$C(p,y,t)=\sum_{i=1}^{N}\sum_{i=1}^{N}b_{ij}\sqrt{p_i}\sqrt{p_j}\,y+\sum_{i=1}^{N}b_ip_i+\sum_{i=1}^{N}b_{it}p_ity$$

$$+b_t\left(\sum_{i=1}^{N}\alpha_ip_i\right)t+b_{yy}\left(\sum_{i=1}^{N}\beta_ip_i\right)y^2+b_{tt}\left(\sum_{i=1}^{N}\gamma_ip_i\right)t^2y \qquad \text{(A1)}$$

p_i : price of i-th input y :production t :time trend

We focus on a part of the quadratic form (A1) by deleting the other terms:

$$C(p,y,t)=\sum_{i=1}^{N}\sum_{j=1}^{N}b_{ij}\sqrt{p_i}\sqrt{p_j}\,y+\sum_{i=1}^{N}b_{it}p_ity+b_{yy}\left(\sum_{i=1}^{N}\beta_ip_i\right)y^2 \qquad \text{(A2)}$$

S.Shishido and O.Nakamura (1992) distinguished three kinds of technical progresses; the first is Hicks neutral, expressed by time; the second is that price change of particular industry affects factor demands of the other industries; both effects are expressed in Stone's RAS. The notable is the third; price competitiveness of mega competition era after 90s affects all the factor demands via reduction of current product price. Hence, put expectation of current price p_j^e to the cost function which S.Shishido and O.Nakamura (1992) has stressed for expressing innovation; factor inputs are reduced by process innovation which is caused by the reduction of the current price in price competitiveness with overseas.

$$C(p,y,t)=\sum_{i=1}^{N}\sum_{j=1}^{N}b_{ij}\sqrt{p_i}\sqrt{p_j}\,y+\sum_{i=1}^{N}b_{it}p_ity+\sum_{i=1}^{N}b_{ip}p_i^ep_iy+b_{yy}\left(\sum_{i=1}^{N}\beta_ip_i\right)y^2 \qquad \text{(A3)}$$

The cost function (A3) is generalized to the MCMS system:

$$C_j^k = \sum_{h1=1}^{K}\sum_{h2=1}^{K}\sum_{i1=1}^{N+2}\sum_{i2=1}^{N+2} b_{i1,i2,j}^{h1,h2,k}\sqrt{p_{i1}^{h1,k}}\sqrt{p_{i2}^{h2,k}}X_j^{kS} \tag{A4}$$

$$+\sum_{h=1}^{K}\sum_{i=1}^{N+2} b_{it}^{hk} p_i^{hk} t X_j^{kS} + \sum_{h=1}^{K}\sum_{i=1}^{N+2} b_{ip}^{hk} p_i^{hk(e)} p_i^{hk} X_j^{kS} + b_{XX}\left(\sum_{h=1}^{K}\sum_{i=1}^{N+2}\beta_i^{hk} p_i^{hk}\right)\left(X_j^{kS}\right)^2$$

in which (N+1) stands for labor and (N+2) for capital. Corresponding factor demand equation in share form is:

$$\frac{x_{ij}^{hk}}{X_j^k} = \sum_{h1=1}^{K}\sum_{i1=1}^{N+2} b_{i1,j}^{h1,k}\sqrt{\frac{p_{i1}^{h1,k}}{p_i^{hk}}} + b_{XX}\beta_i^{hk}X_j^k + b_{it}^{hk}t + b_{ip}^{hk}p_i^e \tag{A5}$$

Ignoring relative prices for different goods will simplified (A.5):

$$\frac{x_{ij}^{hk}}{X_j^k} = \sum_{h1=1}^{K} b_{i1,j}^{h1,k}\sqrt{\frac{p_i^{h1,k}}{p_i^{hk}}} + b_{XX}\beta_i^{hk}X_j^k + b_{it}^{hk}t + b_{ip}^{hk}p_i^e \tag{A6}$$

Appendix 2: Sector Aggregation/Country Code

Sector Aggregation

Category	Classification
1	Agriculture, forestry, fishery and mining (sector1~sector2)
2	Manufacturing (sector3~sector16)
3	Electricity, Gas and Water Supply (sector17)
4	Construction (sector18)
5	Services (sector19~sector36)

Country Code

Code	Country
AUS	Republic of Austria
AUT	Commonwealth of Australia
BEL	Kingdom of Belgium
BGR	Republic of Bulgaria
BRA	Federative Republic of Brazil
CAN	Canada
CHN	People's Republic of China
CYP	Republic of Cyplus
CZE	Czech Republic
DEU	Federal Republic of Germany
DNK	Kingdom of Denmark
ESP	Kingdom of Spain
EST	Republic of Estonia
FIN	Republic of Finland
FRA	French Republic
GBR	The United Kingdom of Great Britain and Northern Ireland
GRC	Hellenic Republic (Greece)
HUN	Republic of Hungary
IDN	Republic of Indonesia
IND	Republic of India

IRL	Ireland
ITA	Republic of Italy
JPN	Japan
KOR	Republic of Korea
LTU	Republic of Lithuania
LUX	Grand Duchy of Luxembourg
LVA	Republic of Latvia
MEX	United Mexican States
MLT	Republic of Malta
NLD	Kingdom of the Netherlands
POL	Republic of Poland
PRT	Portuguese Republic
ROM	Romania
RUS	Russian Federation
SVK	Slovak Republic
SVN	Republic of Slovenia
SWE	Kingdom of Sweden
TUR	Republic of Turkey
TWN	Republic of China
USA	United States of America

References

Berndt, E. and M. S. Kahled (1979), "Parametric Productivity Measurement and Choice among Flexible Functional Forms", *Journal of Political Economy*, Vol.87, pp. 1220-1245.

Blinder, A. S. (1986), "More on Speed of Adjustment in Inventory Models," *Journal of Money, Credit and Banking*, Vo.18, pp. 335-365.

Carpenter, R. E. and D. Levy (1998), "Seasonal Cycles, Business Cycles, and the Co-movement of Inventory Investment and Output", *Journal of Money, Credit, and Banking*, Vol.30, No.3, pp. 331-346.

Childs, G. L. (1967), *Unfilled Orders and Inventories*, North Holland Publishing Company.

Chow, G. C. (1973), "Problem of Economic Policy from the Viewpoint of Optimal Control", *The American Economic Review*, Vol.63, No.5, pp. 825-837.

Christensen, L. R., D. W. Jorgenson and L. J. Lau (1973), "Transcendental Logarithmic Production Function", *Review of Economics and Statistics*, Vol. 55, No. 1, pp. 28-45.

Deaton, A. S. and J. Muellbauer (1980), "An Almost Ideal Demand System", *The American Economic Review*, Vol. 70, pp. 312-326.

Diewert, W. E., T. J. Wales (1987), "Flexible Functional Forms and Global Curvature Conditions", *Econometrica*, Vol. 55, No. 1, pp. 43-68.

Diewert, W. E. and K. J. Fox (2004), "On the Estimation of Returns to Scale, Technical Progress and Monopolistic Markup", Discussion Paper No.04-09, Department of Economics, University of British Columbia.

Diewert, W. E. and K. J. Fox (2008), "On the Estimation of Returns to Scale, Technical Progress and Monopolistic Markups", *Journal of Econometrics*, 145 (1-2), pp. 174-193.

Doeringer, P. and M. Piore (1971), *Internal Labor Markets and Manpower Analysis*, Lexington, Mass. D.C. Heath and Company.

Eichenbaum, M. S. (1989), "Some Empirical Evidence on the Production Level and Production Cost

Smoothing Models of Inventory Investment," *The American Economic Review*, Vol. 79, pp. 853-864.

Fair, R. C. (1994), *Testing Macroeconometric Models*, Harvard University Press.

Fuss, M. (1977), "The Structure of Technology Over Time", *Econometrica*, Vol. 45, pp. 1797-1822.

Hay, G. A. (1970), "Production, Price and Inventory", *The American Economic Review*, Vol. 60, No. 4, pp. 531-545.

Haltiwanger, J. C. and L. J. Maccini (1988), "A Model of Inventory and Layoff Behaviour under Uncertainty," *Economic Journal,* Vol. 98, pp. 731-745.

Hickman, B. (ed.) (1970), *Econometric Models of Cyclical Behavior. New York,* Columbia University Press.

Holt, C. H., F. Modighiani, J.F. Muth and H.A. Simon (1960), *Planning Production, Inventories, and Work Force*, Prentice-Hall, Inc.

Isard, W. (1951), "Interregional and Regional Input-Output Analysis: A Model of a Space-Economy", *The Review of Economics and Statistics*, Vol. 33, No.4, pp. 318-328.

Klein, L. R. (1950), *Economic Fluctuations in the United States 1921-1941*, John Wiley and Sons, Inc.

Kolstad, C. D. and JT. Lee (1993), "The Specification of Dynamics in Cost Function and Factor Demand Estimation", *The Review of Economics and Statistics*, Vol. 75, No.4, pp. 721-726.

Kratena, K. (2005), "Prices and Factor Demand in an Endogenized Input Output Model", *Economic System Research*, Vol. 17, No.1, pp. 47-56.

Kulatilaka, N. (1987), "The Specification of Partial Static Equilibrium Model", *The Review of Economics and Statistics*, Vol. 69, No. 2, pp. 327-335.

Leontief, W. (1953), *Studies in the Structure of the American Economy*, Oxford University Press.

Leontief, W. And A. Strout (1963), "Multiregional Input-Output Analysis", in T. Barna (edi.), *Structural Interdependence and Economic Development,* London: St. Martin's Press.

Lipsey, R. G. (1960), "The Relation between Unemployment and the Rate of Change of Money Wage Rates of the United Kingdom, 1862-1957: A Further Analysis", *Economica*, pp. 1-31.

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

Maccini, L. J. (1976), "An Aggregate Dynamic Model of Short-Run Price and Output Behavior," *The Quarterly Journal of Economics*, Vol. XC, No.2, pp. 177-196.

Maccini, L. J. (1984), "The Interrelationship Between Price and Output Decisions and Investment Decisions", *Journal of Monetary Economics*, Vol. 13, pp. 41-65.

Mankiw, N. G. (1985), "Small Menu Costs and Large Business Cycles: A Macroeconomic Model of Monopoly," *The Quarterly Journal of Economics*, Vol. 100, pp. 529-538.

Melitz, M.J. (2003), "The Impact of Trade on Intra-industry Reallocations and Aggregate Industry Productivity", *Econometrica*, Vol. 71, No. 6, pp. 1695-1725.

Modighiani, F. (1957), *Business Reasons for Holding Inventories and Their Macroeconomic Implications,* Studies of Income and Wealth, Vol. 19.

Mongelli, I., F. Neuwahl and J. M. Rueda-Cantuche (2010) "Integrating a Household Demand System in the Input-Output Framework", *Economic Systems Research*, Vol. 22 No. 3, pp. 201-222.

Morrison, C. (1988), "Quasi-fixed Inputs in the U.S. and Japanese Manufacturing: a Generalized Leontief Restricted Cost Function Approach", *The Review of Economics and Statistics*, Vol. 70 No. 2, pp. 275-287.

Nakamura, S. (1990), "A Non-homothetic Generalized Leontief Cost Function Based on Pooled Data", *The Review of Economics and Statistics*, Vol. 72, No. 4, pp. 649-656

Nakamura, S. (2001), "A Non-homothetic Globally Concave Flexible Cost Function and its Application to Panel Data," *The Japanese Economic Review*, Vol.52, No. 2, pp. 208-223.

Negishi, T. (1961), "Monopolistic Competition and General Equilibrium", *The Review of Economic Studies*, Vol. 28, No. 3, pp. 196-201.

Pindyck, R. S. and J. J. Rotemberg (1983), "Dynamic Factor Demands and the Effects of Energy Price Shocks", *The American Economic Review*, Vol. 73, No.5, pp. 1066-1079.

Saito, M (1971), "An Interindustry Study of Price Formation", *The Review of Economics and Statistics,* Vol. 53, pp. 11-25.

Shibata, T. and H. Kosaka (2013), "An Input-Output Model Building for Nine Regions of Japanese Economy Based on Microeconomic Foundation", *The Studies in Regional Science*, Vol. 42, No. 4, pp. 897-909.

Shishido, S. and O. Nakamura (1992), "Induced Technical Progress and Structural Adjustment: A Multi-Sectoral Model Approach to Japan's Growth Alternatives", *The Journal of Applied Input Output Analysis,* Vol. 1, No.1, pp. 1-23.

Turnovsky, S. J. (1977), *Macroeconomic Analysis and Stabilization Policy*, Cambridge University Press, Cambridge.

Weitzman, M. L. (1985), "The Simple Macroeconomics of Profit Sharing", *The American Economic Review*, Vol. 75, pp. 937-953.

Why is the life cycle of happiness unusual in Japan?

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Abstract

In contrast to the common finding that life satisfaction is U-shaped with age, recent studies for Japan found an L-shaped pattern of life satisfaction, with initial decline between young and middle ages, but no recovery in the old age. We studied the source of this unusual finding by two versions of age-cohort-period model, and found that the addition of cohort effects could explain away the L-shaped pattern in the life cycle of happiness. The result remained robust to adding fixed effects across individuals, with several significant asymmetries between men and women in determinants of life satisfaction.

Keywords: Happiness, well-being, life-cycle, age-period-cohort model.

JEL Classification Numbers: D91, I31.

1. Introduction

This paper attempts to explain an unusual finding in previous studies about the life cycle of happiness in Japan. While it has become common to find happiness U-shaped over the life cycle, with the lowest point reached in the early 40s and a recovery up to the old age (Blanchflower and Oswald, 2004, 2008; Clark, 2007), a different pattern was reported for Japan (Cabinet Office, 2009; Tsutsui et al., 2010; Commission on Measuring Well-being, 2011). Specifically, Japan does not seem much different in the first half of the life cycle, with a declining happiness from young age to the early 40s. But a notable divergence appears in the second half of life cycle, when happiness in Japan does not increase after the 40s, but largely stays flat (Tsutsui et al., 2010). Evidently, the age-happiness profile in Japan is not U-shaped like in many other countries, but L-shaped, with a conspicuous lack of increased happiness in the old age. Overall, it is the elderly in Japan that appear to be the least happy across different age groups (Commission on Measuring Well-being, 2011, p. 16).

As an explanation for this peculiar pattern of the age-happiness profile in Japan, Tsutsui et al. (2010) suggested a possible bias in estimated age effects due to omitted cohort effects (p. 51-53). This potential bias in age effects was previously emphasized by Clark (2007), who examined whether cohort effects may account for the U-shape in happiness in the United Kingdom, but found that U-shape remained largely unchanged even with included cohort effects. So far, no similar study has been done with Japanese data.

Our goal in this paper is to verify whether cohort effects may explain the L-shape in

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age- happiness profile in Japan. In practice, when cohort effects are added to regression specifications, they are commonly used together with the effects of age and calendar year. This creates an identification problem among age, cohort and period effects, because these three effects are linearly dependent, with the individual's age equal exactly to the current year minus the year of birth. The identification problem in age-period-cohort (A-P-C) models has long been known in economics (Deaton and Paxson, 1994), and it can be solved by imposing restrictions on parameter estimates of the A-P-C effects.

In this paper, we consider two approaches that solve the identification problem. First, we deal with the exact linearity among A-P-C effects by specifying one of these effects with a non-linear function, as a part of a semiparametric regression model (Wunder et al., in press; Movshuk, 2012). We also consider an alternative restriction from Deaton and Paxson (1994), who solved the identification problem by restricting period effects to be orthogonal to a linear time trend[1].

The key assumption of the Deaton-Paxson (D-P) restriction is that period effects do not contain linear time trends. If linear trends are actually present in period effects, the D-P approach would attribute them to age and cohort effects, leading to biased estimates of these effects (Deaton and Paxson, 1997, p. 103). With our semiparametric approach to solve the identification problem, we could verify the validity of the D-P assumption, and found no significant linear time trend in estimated period effects. This made either of our two approaches applicable to estimating A-P-C models of happiness in Japan.

2. Data

We used data from the Osaka University's 21 Century Center of Excellence program, which con- ducts "Preference and Life Satisfaction Survey" (PLiSS). One important advantage of the dataset is its panel structure. Other features of the survey were described in previous studies with the PLiSS data (such as Kamesaka et al. (2010) and Tsutsui et al. (2010)).

3. Model specification

Our regression specifications assume an experienced personal utility $U_{i,t}$ for individual i at time t that depends of a vector of personal and demographic characteristics $x_{i,t}$, with $U_{i,t} = u(x_{i,t})$. The utility $U_{i,t}$ is known only to the individual i, who reports it as reported happiness R, which is a function of Ui,t, namely Ri,t = r (Ui,t), or Ri,t = r (u (xi,t)). The reported happiness $R_{i,t}$ depends on $x_{i,t}$ through parametric and nonparametric effects in a semiparametric regression model $R_{i,t} = r\left(u\left(x_{i,t}\right)\right) + \varepsilon_{i,t}$, where $\varepsilon_{i,t}$ is a conventional disturbance term.

The vector of explanatory variables $x_{i,t}$ includes personal judgment about standard of living[2], age (which is specified as a smooth nonparametric term s(age) to avoid the

[1] Another solution to the identification problem was suggested by Clark (2007) and Blanchflower and Oswald (2008), who assumed that regression parameters among A-P-C effects have different time blocks. Namely, Clark (2007) represented age effects with 5-year age blocks, and left cohort and period effects unrestricted (as one-year dummy variables), and a similar restriction was used by Blanchflower and Oswald (2008). However, the approach was questioned by de Ree and Alessie (2011), who showed that slight modifications in the structure of time blocks may greatly change estimates of age effect. We applied the same sensitivity check to Japanese data, and confirmed the result of de Ree and Alessie (2011) that changing the time span of age blocks greatly modified the pattern of estimated age effects. Due to this shortcoming, we do not consider the third solution here.

[2] The variable is a proxy for relative income, and was found to have a superior explanatory power in Japanese data, as compared with absolute levels of income (Tsutsui et al., 2010, p. 59).

identification problem), time t and various demographic and personal characteristics.

Our baseline specification is essentially a semiparametric age-period model, which we refer as Model 1:

$$R_{i,t} = s\left(age_{i,t}\right) + \alpha_t' D_t + \beta_t' x_{i,t} + \varepsilon_{i,t} \quad (1)$$

In Model 2, we add a set of dummy variables for birth cohorts Dc, with birth year defined by c = t − a, producing the following age-period-cohort model:

$$R_{i,t} = s\left(age_{i,t}\right) + \alpha_t' D_t + \alpha_c' D_c + \beta_t' x_{i,t} + \varepsilon_{i,t} \quad (2)$$

In Model 3, we explore the validity of the Deaton-Paxson solution to the identification problem, and examine their key assumption that period effects are orthogonal to a linear time trend. To testthis assumption, we replace the matrix of time dummies Dt with a linear time trend t, which yields Model 3:

$$R_{i,t} = s\left(age_{i,t}\right) + \gamma_t' t + \alpha_c' D_c + \beta_t' x_{i,t} + \varepsilon_{i,t} \quad (3)$$

The Deaton-Paxson restriction is valid if the null hypothesis $H_0 : \gamma_t = 0$ is not rejected by the data.

In Models 4 and 5, we apply the Deaton-Paxson restrictions on the period effect (namely, $\sum \hat{\alpha}_t = 0$ and $\sum \hat{\alpha}_t t = 0 = 0$), which in practice means using a transformed matrix of time dummies, which we denote by D^*. After replacing time dummies *Dt* in Models 2 and 3 by D^*, age effects can be estimated with an unrestricted matrix of age dummies *Da* (rather than the smooth age effect $s(age_{i,t})$ that we used in Models 2 and 3). After substituting D_a for $s(age_{i,t})$, we obtained the following Models 4 and 5:

$$R_{i,t} = \alpha_a' D_a + \alpha_t' D_t^* + \beta_t' x_{i,t} + \varepsilon_{i,t} \quad (4)$$

$$R_{i,t} = \alpha_a' D_a + \alpha_t' D_t^* + \alpha_c' D_c + \beta_t' x_{i,t} + \varepsilon_{i,t} \quad (5)$$

which only differ by the addition of cohort effects in Model 5.

Our final Model 6 used the panel structure of the PLiSS dataset, and introduced fixed effects α_i across individuals:

$$R_{i,t} = \alpha_i + \alpha_a' D_a + \alpha_t' D_t^* + \alpha_c' D_c + \beta_t' x_{i,t} + \varepsilon_{i,t} \quad (6)$$

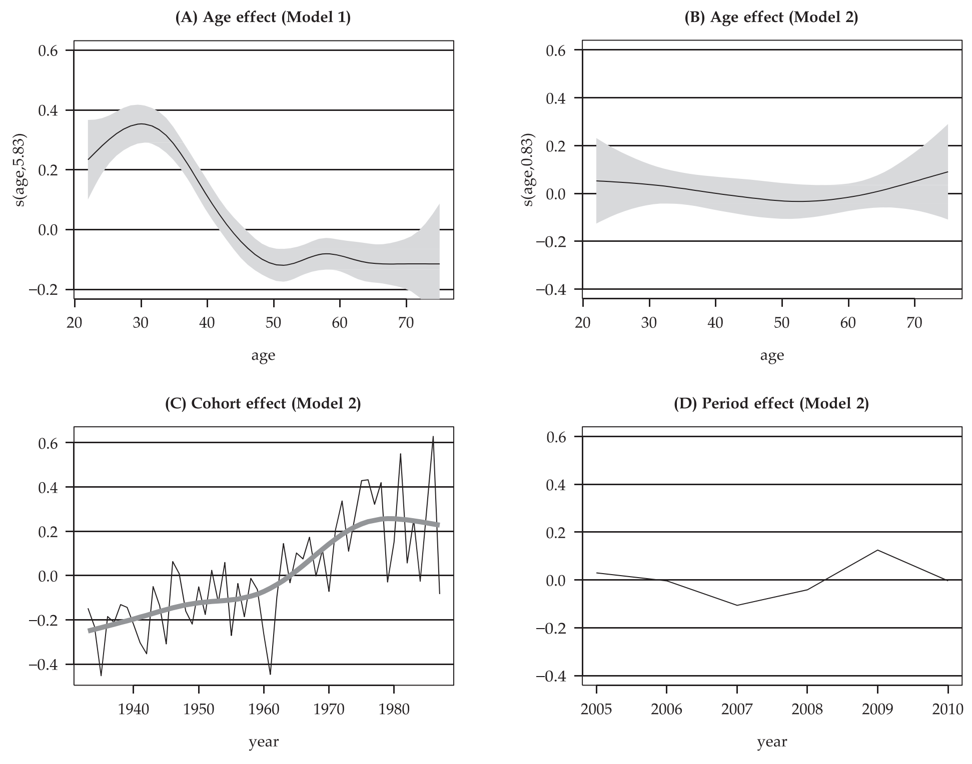
With this model, we could examine how sensitive our cross-sectional specifications in Models 1-5 to the addition of fixed effects for different individuals, which could account for inherent personality traits, with potentially large effect on subjective well-being.

4. Results

Table 1 presents results of estimating our three semiparametric models, while Figure 1 plots estimates for age, cohort and period effects in Models 1 and 2. When cohort effects were omitted in Model 1, we confirmed the peculiar pattern for Japan that the age effect on happiness is L-shaped (Panel A of Figure 1). The highest happiness is reached in the early 30s, with a constant decline until the early 50, and little change in the later part of the life cycle. As for parametric estimates for Model 1, they are reported in Table 1. By far the largest impact on happiness was from differences in standards of living. Compared with individuals who placed themselves in the reference group 1 (the lowest standard of living), happiness in group 7 (the highest standards of living[3]) was higher by 3.56 points, and had a large t-value (50.03). It is also noteworthy that the positive effect on happiness was increasing almost linearly across different levels of standards of living, with almost no flattening in marginal additions to the effect. The second largest impact on happiness was from differences in marital status, with marriage increasing happiness by 0.58 points, in comparison with the reference category of single individuals. Finally, excellent health (or more precisely, the lack of worries about health) increased happiness by 0.50 points compared with the reference category of people who worried about their health.

When cohort effects were added in Model 2, age-happiness profile was no longer L-shaped, but flat (as shown in Panel B of Figure 1). On the other hand, estimates of cohort effects showed progressively increasing happiness across more recent birth cohorts, especially for those who were born between the early 1960s and 1980s. Evidently, the reduced age effect between the early 30s and 50s in Model 1 was due to the increasing happiness among individuals, born in the 1960s and the early part of the 1970s.

Figure 1 Estimates of age, cohort and period effects in semiparametric models.



[3] Original data differentiated 11 categories, but contained relatively few responses for the lowest and highest standards of living. After aggregating these extreme categories, we obtained 7 categories with sufficiently large number of responses

Table 1 Regression estimates for semiparametric regression models

	(1)		(2)		(3)	
	Age-Period model		Age-Period-Cohort model		Age-Time trend- Cohort model	
Gender: women	0.19***	(6.86)	0.19***	(6.75)	0.19***	(6.83)
Standard of living: 2	0.79***	(13.12)	0.80***	(13.26)	0.80***	(13.16)
Standard of living: 3	1.35***	(23.14)	1.36***	(23.29)	1.35***	(23.17)
Standard of living: 4	1.96***	(35.96)	1.97***	(36.08)	1.97***	(35.95)
Standard of living: 5	2.47***	(42.42)	2.47***	(42.30)	2.46***	(42.16)
Standard of living: 6	2.96***	(48.45)	2.96***	(48.38)	2.95***	(48.25)
Standard of living: 7	3.56***	(50.03)	3.56***	(49.91)	3.55***	(49.75)
Health: neutral	0.18***	(7.02)	0.17***	(6.78)	0.18***	(6.78)
Health: not worried	0.50***	(18.16)	0.50***	(17.96)	0.50***	(18.05)
Marital: married	0.58***	(10.96)	0.58***	(10.97)	0.59***	(11.15)
Marital: divorced	0.23***	(3.35)	0.23***	(3.30)	0.24***	(3.37)
Marital: widowed	0.12	(1.46)	0.14	(1.65)	0.14	(1.69)
Job: unemployed	−0.05	(0.49)	−0.04	(0.44)	−0.01	(0.10)
Job: out of labor force	0.29***	(6.11)	0.29***	(6.12)	0.32***	(6.69)
Work: company empl.	0.17***	(3.59)	0.16***	(3.39)	0.19***	(3.96)
Work: pub. empl.	0.30***	(4.75)	0.30***	(4.79)	0.33***	(5.20)
Work: manager.	0.29***	(3.86)	0.30***	(3.98)	0.32***	(4.28)
Work: self-empl.	0.26***	(4.83)	0.26***	(4.81)	0.28***	(5.29)
Religion: neutral	−0.01	(0.42)	−0.02	(0.61)	−0.02	(0.65)
Religion: strong	0.49***	(11.19)	0.49***	(11.33)	0.49***	(11.31)
Educ: 2-year college	0.15***	(4.67)	0.15***	(4.61)	0.15***	(4.64)
Educ: university	0.17***	(5.78)	0.17***	(5.98)	0.17***	(6.00)
Educ: graduate	0.08	(1.01)	0.10	(1.34)	0.11	(1.41)
Child: 1	0.16***	(3.01)	0.16**	(3.15)	0.16**	(3.10)
Children: 2	0.17***	(3.59)	0.18***	(3.79)	0.17***	(3.71)
Children: 3 or more	0.21***	(4.30)	0.23***	(4.57)	0.22***	(4.48)
Home: own with loan	0.03	(0.99)	0.02	(0.62)	0.02	(0.60)
Home: rent	−0.03	(1.06)	−0.05	(1.51)	−0.05	(1.57)
Smoke: occasional	−0.17***	(3.76)	−0.16***	(3.64)	−0.16	(3.61)
Smoke: 10 cigs	−0.26***	(6.12)	−0.27***	(6.23)	−0.27***	(6.24)
Smoke: 20 cigs and more	−0.22***	(6.94)	−0.23***	(6.98)	−0.23***	(7.02)
Drink: occasional	−0.05	(1.66)	−0.05	(1.55)	−0.05	(1.57)
Drink: 1 per day	−0.02	(0.58)	−0.03	(0.65)	−0.03	(0.66)
Drink: 3 per day	0.08	(1.75)	0.09*	(2.01)	0.09*	(2.02)
Time trend					0.01	(1.01)
Year effect	Yes		Yes		No	
Cohort effect	No		Yes		Yes	
Region effect	Yes		Yes		Yes	
Estimated degrees of freedom for nonparametric effects						
s(age)	5.83***		0.83		0.06	
Sample size	18, 983		18, 983		18, 983	
Deviance explained	0.313		0.319		0.317	

Absolute t statistics in parentheses
$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$
Reference categories are (1) gender: male, (2) standard of living: 1 (lowest), (3) health: worried, (4) marital: never married, (5) job: employed, (6) work: not employed, (7) religion: weak, (8) educ: secondary school, (9) child: none, (10)home: owner, no loan, (11) smoke: no, (12) drink: no.

Table 2 Regression estimates with the Deaton-Paxson restriction.

	(1)		(2)		(3)	
	Age-Period model		Age-Period-Cohort model		Fixed effect model	
Gender: women	0.19***	(4.87)	0.19***	(4.92)		
Standard of living: 2	0.79***	(6.60)	0.80***	(6.89)	0.45***	(4.56)
Standard of living: 3	1.36***	(11.47)	1.37***	(11.82)	0.73***	(6.93)
Standard of living: 4	1.96***	(17.18)	1.98***	(17.85)	1.10***	(10.12)
Standard of living: 5	2.47***	(21.33)	2.47***	(21.93)	1.36***	(12.04)
Standard of living: 6	2.95***	(25.28)	2.96***	(26.16)	1.59***	(13.70)
Standard of living: 7	3.56***	(28.62)	3.57***	(29.43)	1.89***	(14.70)
Health: neutral	0.18***	(5.53)	0.17***	(5.40)	0.08*	(2.29)
Health: not worried	0.51***	(13.21)	0.50***	(13.14)	0.17***	(3.97)
Marital: married	0.57***	(7.71)	0.58***	(7.98)	0.45**	(2.99)
Marital: divorced	0.23*	(2.33)	0.24*	(2.44)	0.24	(1.67)
Marital: widowed	0.11	(1.15)	0.14	(1.39)	−0.27	(1.17)
Job: unemployed	−0.05	(0.36)	−0.05	(0.36)	0.05	(0.31)
Job: out of labor force	0.30***	(5.32)	0.29***	(5.21)	0.01	(0.14)
Work: company empl.	0.17**	(2.96)	0.16**	(2.78)	−0.06	(0.88)
Work: pub. empl.	0.30***	(3.48)	0.30***	(3.56)	−0.12	(0.80)
Work: manager.	0.29***	(3.55)	0.30***	(3.67)	0.16	(1.20)
Work: self-empl.	0.25***	(4.00)	0.25***	(3.97)	0.08	(0.92)
Religion: neutral	−0.01	(0.36)	−0.02	(0.54)	−0.02	(0.42)
Religion: strong	0.49***	(9.12)	0.49***	(9.16)	0.04	(0.49)
Educ: 2-year college	0.15***	(3.40)	0.15***	(3.43)	−0.01	(0.09)
Educ: university	0.17***	(4.38)	0.17***	(4.48)	0.08	(0.65)
Educ: graduate	0.08	(0.90)	0.11	(1.16)	−0.08	(0.25)
Child: 1	0.17*	(2.39)	0.17*	(2.46)	0.34**	(2.88)
Children: 2	0.17**	(2.83)	0.18**	(2.91)	0.36**	(3.00)
Children: 3 or more	0.22**	(3.22)	0.22***	(3.36)	0.17	(1.48)
Home: own with loan	0.03	(0.74)	0.02	(0.56)	−0.01	(0.26)
Home: rent	−0.04	(0.73)	−0.05	(1.03)	−0.16	(1.19)
Smoke: occasional	−0.17**	(2.69)	−0.17**	(2.66)	−0.03	(0.52)
Smoke: 10 cigs.	−0.26***	(4.84)	−0.26***	(4.88)	−0.01	(0.11)
Smoke: 20 cigs. and more	−0.22***	(5.23)	−0.22***	(5.30)	0.08	(0.79)
Drink: occasional	−0.05	(1.22)	−0.04	(1.08)	−0.06	(0.93)
Drink: 1 per day	−0.02	(0.49)	−0.03	(0.54)	−0.07	(0.79)
Drink: 3 per day	0.08	(1.40)	0.09	(1.67)	−0.11	(1.07)
Intercept	3.09***	(6.63)	18.68*	(2.15)	5.56**	(3.17)
Year effect	*Yes*		*Yes*		*Yes*	
Cohort effects	*No*		*Yes*		As fixed effects	
Region effects	*Yes*		*Yes*		*No*	
Sample size	18, 983		18, 983		18, 983	
Adjusted R^2	0.312		0.316		0.069	

Absolute *t* statistics in parentheses
$*p< 0.05$, $**p< 0.01$, $***p< 0.001$ Reference categories are the same as in Table 1.

In Model 3, we replaced the set of time dummies with a linear time trend; the estimate of time trend was positive, but had insignificant t-statistics (1.01), as shown in column (3) of Table 1, which supports the validity of D-P restriction to solve the identification problem. Table 2 reports results with the D-P approach. Overall, estimates for Models 4 and 5 (in columns (1) and (2) of Table 2) turned very similar to comparable estimated for Models 1 and 2 (in columns (1) and (2) of Table 1). As for age effect, it was highly significant in Model 4 (column (1) of Table 3), but turned insignificant after adding cohort effects in Model 5, with p-value is only 0.645 (column (2) of Table 3).

After we added fixed effects to Model 6, the magnitude of many parameter estimates was reduced compared with previous models with no fixed effects. For example, the effect from the highest standard of living was halved, from 3.57 points in Model 5 to 1.89 points in Model 6. Similarly, the effect of excellent health increased happiness by only 0.17 points, which is about one third of the comparable estimates from excellent health in Model 5. Moreover, many groups of variables were no longer statistically significant. Results for total sample are shown in first three columns of Table 3. Only five groups of variables remained significant at 5 percent significance level: period effects, standards of living, health, marital status, and children. When we split the sample into men and women, we found both similarities and sharp differences between genders. For both men and women, differences in standards of living and health remained important. On the other hand, marital status was significant for men only (with p-value less than 0.001), while for women the corresponding p-value was 0.186. We also found a similar asymmetric effect for the number of children, which turned significant for women (p-value = 0.034), while for men the corresponding p-value was only 0.259.

Table 3 P-values in the hypothesis testing for groups of dummy variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Model:	All sample			Men			Women		
	A-P	A-P-C	FE	A-P	A-P-C	FE	A-P	A-P-C	FE
Age effect	< 0.001	0.645	0.152	0.000	0.966	0.098	0.000	0.370	0.138
Cohort effect		< 0.001			< 0.001			< 0.001	
Period effect	< 0.001	< 0.001	0.004	0.001	0.002	0.019	0.005	0.001	0.088
Standard of living	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Health	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.015	< 0.001	< 0.001	0.019
Marital status	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.186
Have job?	< 0.001	< 0.001	0.954	0.001	0.001	0.106	< 0.001	< 0.001	0.070
Job type	< 0.001	< 0.001	0.292	0.790	0.594	0.907	0.006	0.005	0.162
Religion	< 0.001	< 0.001	0.656	< 0.001	< 0.001	0.557	< 0.001	< 0.001	0.283
Education	< 0.001	< 0.001	0.847	0.016	0.023	0.306	< 0.001	< 0.001	0.700
Children	0.015	0.010	0.015	0.055	0.024	0.259	0.126	0.136	0.034
House	0.426	0.360	0.484	0.451	0.543	0.352	0.004	0.002	0.767
Smoking	< 0.001	< 0.001	0.640	< 0.001	< 0.001	0.320	< 0.001	< 0.001	0.308
Alcohol	0.047	0.028	0.709	0.010	0.002	0.942	0.342	0.354	0.779
Region	0.000	< 0.001		< 0.001	< 0.001		0.007	0.004	

Note: A-P and A-P-C denotes age-period and age-period-cohort models (*i.e.*, Model 4 and Model 5, respectively). FE refers to Model 6 with fixed effects.

5. Conclusion

We reached three major conclusions in this paper. First we confirmed previous studies that without cohort effects, the age-happiness profile is L-shaped in Japan, with the gradual decline between the young and middle age, and little change in happiness after the middle age. Second, we found that after adding cohort effects, the age-happiness profile becomes flat in our semiparametric A-P-C model. Similarly, the A-P-C model with the Deaton-Paxson restriction on period effects resulted in statistically insignificant estimates of age effect as a whole. Third, we examined whether our results would hold after accounting for fixed effects across individuals. The fixed-effect model was only computationally feasible with the Deaton-Paxson approach to the identification problem, and confirmed our previous finding that age does not have significant effect on happiness. Instead, four other factors proved important determinants of happiness. Differences in the standard of living and health status were important for both men and women. In addition, we found significant asymmetries in determinants of happiness between genders: marital status was important for men, but not for women, while children were important for women, but not for men. The result is similar to Kamesaka et al. (2010), who also found important differences between Japanese men and women in significant determinants of happiness.

References

Blanchflower, D. G. and A. J. Oswald (2004), "Well-being over time in Britain and the USA", *Journal of Public Economics*, 88, pp. 1359–1386.

Blanchflower, D. G. and A. J. Oswald (2008), "Is well-being U-shaped over the life cycle?", *Social Science & Medicine*, 66, pp. 1733–1749.

Cabinet Office (2009), *White paper on life of the nation in the fiscal year 2008 (Heisei 20-nen kokumin seikatu hakusho)* [in Japanese], Tokyo: Cabinet Office, the Government of Japan.

Clark, A. E. (2007), "Born to be mild? Cohort effects don't (fully) explain why well-being is u-shaped in age", *IZA Discussion Papers*, 3170, Institute for the Study of Labor (IZA).

Commission on Measuring Well-being (2011), *Measuring national well-being (proposed well-being indicators)*, the Commission on Measuring Well-being, Tokyo, report from December 5th, 2011.

de Ree, J. and R. Alessie (2011), "Life satisfaction and age: Dealing with underidentification in age-period-cohort models", *Social Science & Medicine*, 73, pp. 177–182.

Deaton, A. S. and C. Paxson (1994), "Saving, growth, and aging in Taiwan", in Studies in the Economics of Aging (Ed.) D. Wise, University of Chicago Press, Chicago, pp. 331–357.

Deaton, A. S. and C. Paxson (1997), "The effect of economic and population growth on national saving and inequality", *Demography*, 34, pp. 97–114.

Kamesaka, A., K. Yoshida and F. Ohtake (2010), *Life stages and gender differences in happiness (Raifu suteji no henka to danjo no koufukudo)* [in Japanese], Behavioral Economics [Koudou keizaigaku], 4, pp.183–186.

Movshuk, O. (2012), "Why is life satisfaction U-shaped in age?", *Journal of Behavioral Economics and Finance*, 4, pp. 133–138.

Tsutsui, Y., F. Ohtake and S. Ikeda (2010), *The reason why you are unhappy (Naze anata ha fushiawase na no ka)* [in Japanese], *in Happiness in Japan: Inequality, Labor and Family [Nihon no koufukudo: kakusa, roudou, kazoku]* (Eds.) F. Ohtake, S. Shiraishi and Y. Tsutsui, Nippon Hyoron Sha.

Wunder, C., A. Wiencierz, J. Schwarze and H. Ku¨chenhoff (in press), "Well-being over the life span: semiparametric evidence from British and German longitudinal data", *Review of Economics and Statistics*, accepted for publication.

An Oligopolistic Market Model of Multi-Country/Multi-Sector System for the 2005 BRICs International Input-Output Table

Tsubasa Shibata*

Abstract

The purpose of this study is to explain the international trade by developing a multi-country/multi-sector model, seven countries and seven sectors, which is built upon the 2005 BRICs International Input-Output Table. This model is the static one which determines sectoral price and output simultaneously along the framework of input-output table. In order to describe the reality of the strategic interaction among firms, we incorporate the oligopolistic market where there are some homogenous goods in the domestic market and the differentiated seven goods produced by each country's firm in the world market.

KEYWORDS: International Input-Output, BRICs, Oligopolistic Competition, the number of firms

JEL classification: F5, F6, C3

1. Introduction

Today, the international trade has become an increasingly complex. It is virtually impossible to explain the real global economy by traditional perfect competition structure. The relaxation of assumptions on the perfect competition has led to develop imperfect competition. The pioneer works can date back to Dixit-Stiglitz (1977) and Krugman (1979, 1980). They developed the monopolistic competition which considers the implication of increasing returns to scale and the product differentiation in general equilibrium. Afterwards, the theory of monopolistic competition has been applied in many fields. There has been vast literature and empirical analysis. The major theoretical break-through toward Krugman (1980) model is Melitz (2003) who incorporated firm heterogeneity. Others are associated with Helpman et al. (2004) and Bernard, Eaton et al. (2003). Their models have provided the new ways of thinking about the mechanism of firm heterogeneity and the participation in international markets. However, there remain some worries to monopolistic competition. Certainly, firm heterogeneity in productivity has been playing an increasingly prominent. But, Melitz's model is just based on the field monopolistic competition by Krugman. There are still some descriptions which cannot trace realism of contemporary international trade enough.

As for the ongoing question, as Peter Neary (2009) pointed out, the monopolistic competition ignores the main subject of strategic market among firms. There are uncountable huge amount of firms. They are assumed to be as so negligibly small that they don't impact

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on others in whole economy. That is to say, it is assumed that they are not engaged in the strategy. In this sense, this assumption is not over the perfect competition. In addition, firms have demand curve of downward sloping. It means that firms' prices are not affected by firms' market shares. The mechanism of price determination is quite similar to monopoly market. Therefore, although the development of monopolistic market has been sophisticated, it cannot overcome the perfect competition or monopoly market. The crucial aspect reflecting realism, namely the strategic interaction among rival firms, has been put aside.

When we see the real international economy, a few main firms seem to exist and have significant powers in own market, competing with rivals strategically. In fact, there are some stylized facts that capture the realism of oligopolistic market by partial equilibrium approach. Bernard et al. (2003) have shown the important fact by using huge US micro-plant data. Exporters are not atomic but the minority. The most of firm entering export markets is productive firms enough to overcome the costs. Also, firm exporting anything was only 12 percent in 1992. Most exporters tend to sell mostly products in domestic market. Then, about 2/3 of exporters sell less than 10 percent of their output abroad. These seem to be very suggestive findings. They show that there are not uncountable firms, but a few firms who have some power in the market. International trade tends to be based on the oligopolistic market. However, there is also a limitation of partial equilibrium approach. It is imperative to build the model in general equilibrium which can account for the strategic interaction among rival markets as well as between goods and factor.

Therefore, we attempt to construct a Multi-Country/Multi-Sector model (MCMS) which incorporates the oligopolistic market. In order to realize empirical analysis, we utilize BRICs international input-output table in 2005. International input-output table is powerful tool to capture empirically international economy in terms of the comprehensive and consistent system which can see interaction among regions or industries. In particular, endogenized countries of BRICs international input-output table are not only the BRIC, but also advanced areas (EU25, Japan, and the United States). These endogenized seven regions' GDP reaches to about 80 percent of world GDP. In this way, our model has the general equilibrium framework of oligopolistic market which deals with global competition among seven countries via seven sectors.

Our model has two characteristics. First, we assume the homogenous and differentiated oligopoly market in MCMS system. The homogenous oligopoly market is introduced into individual domestic commodity market. In contrast, the world total market becomes differentiated market because plural commodities with different prices are sold. They compete with each other for product differentiation in the international market. Second, our model relaxes two assumptions: one is an assumption that firms enter/exit in response to economic profit and loss, and the other is that the profit condition is zero. These assumptions are based on exceedingly normative suppositions in the long-term view whilst our study in the short-term perspective assumes that the firms don't enter/exit. Besides, since it is supposed that firms have an expectation to gain some profits, we don't have the market clearing of profit zero condition. Above all, the framework of this model is developed without distorting the basic structure of input-output table.

This paper is organized as follows; section 2 explains the data, section 3 illustrates the model structure, and section 4 demonstrates the simulation result, and finally section 5 concludes.

2. BRICs International Input-Output Table

The model is constructed the BRICs International Input-Output Table in 2005 which is compiled by Institute of Developing Economies-Japan External Trade Organization (IDE-JETRO). This table covers seven specific regions: Brazil, China, India, Japan, EU25[1], Russia and The United States. In addition, the sector classification of original input-output table is composed of 7 sectors as Table 2.

Table 1 Regions

	Classification
1	Brazil
2	China
3	EU25
4	India
5	Japan
6	Russia
7	USA

Table 2 Sector Classification

	Classification
1	Agriculture, livestock, forestry and fishery
2	Mining and quarrying
3	Manufacturing
4	Electricity, gas and water supply
5	Construction
6	Trade and transport
7	Services

1 EU25 is defined to include the following 25 countries: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, the United Kingdom.

Figure 1 The schematic image of the 2005 BRICs International Input-Output Table

		Intermediate Demand (A)							Final Demand (FD*)							Export to R.O.W.	Statistical Discrepancy	Total Outputs
		BRZ	CHN	IND	JPN	EU25	RUS	USA	BRZ	CHN	IND	JPN	EU25	RUS	USA			
Intermediate Input (A)	BRZ	XV^{BB}	XV^{BC}	XV^{BG}	XV^{BJ}	XV^{BO}	XV^{BR}	XV^{BU}	FD^{BB}	FD^{BC}	FD^{BG}	FD^{BJ}	FD^{BO}	FD^{BR}	FD^{BU}	EX^{BW}	SD^{B}	X^{B}
	CHN	XV^{CB}	XV^{CC}	XV^{CG}	XV^{CJ}	XV^{CO}	XV^{CR}	XV^{CU}	FD^{CB}	FD^{CC}	FD^{CG}	FD^{CJ}	FD^{CO}	FD^{CR}	FD^{CU}	EX^{CW}	SD^{C}	X^{C}
	IND	XV^{GB}	XV^{GC}	XV^{GG}	XV^{GJ}	XV^{GO}	XV^{GR}	XV^{GU}	FD^{GB}	FD^{GC}	FD^{GG}	FD^{GJ}	FD^{GO}	FD^{GR}	FD^{GU}	EX^{GW}	SD^{G}	X^{G}
	JPN	XV^{JB}	XV^{JC}	XV^{JG}	XV^{JJ}	XV^{JO}	XV^{JR}	XV^{JU}	FD^{JB}	FD^{JC}	FD^{JG}	FD^{JJ}	FD^{JO}	FD^{JR}	FD^{JU}	EX^{JW}	SD^{J}	X^{J}
	EUR	XV^{OB}	XV^{OC}	XV^{OG}	XV^{OJ}	XV^{OO}	XV^{OR}	XV^{OU}	FD^{OB}	FD^{OC}	FD^{OG}	FD^{OJ}	FD^{OO}	FD^{OR}	FD^{OU}	EX^{OW}	SD^{O}	X^{O}
	RUS	XV^{RB}	XV^{RC}	XV^{RG}	XV^{RJ}	XV^{RO}	XV^{RR}	XV^{R+-U}	FD^{RB}	FD^{RC}	FD^{RG}	FD^{RJ}	FD^{RO}	FD^{RR}	FD^{RU}	EX^{RW}	SD^{R}	X^{R}
	USA	XV^{UB}	XV^{UC}	XV^{UG}	XV^{UJ}	XV^{UO}	XV^{UR}	XV^{UU}	FD^{UB}	FD^{UC}	FD^{UG}	FD^{UJ}	FD^{UO}	FD^{UR}	FD^{UU}	EX^{UW}	SD^{U}	X^{U}
Freight and Insurance cost		FRE^{B}	FRE^{C}	FRE^{G}	FRE^{J}	FRE^{O}	FRE^{R}	FRE^{U}	FRE^{B}	FRE^{C}	FRE^{G}	FRE^{J}	FRE^{O}	FRE^{R}	FRE^{R}			
Import from the R.O.W. (FOB)		IM^{WB}	IM^{WC}	IM^{WG}	IM^{WJ}	IM^{WO}	IM^{WR}	IM^{WU}	IM^{WB}	IM^{WC}	IM^{WG}	IM^{WJ}	IM^{WO}	IM^{WR}	IM^{WU}			
Duties and Import Commodity Taxes		$DUTY^{B}$	$DUTY^{C}$	$DUTY^{G}$	$DUTY^{J}$	$DUTY^{O}$	$DUTY^{R}$	$DUTY^{U}$	$DUTY^{B}$	$DUTY^{C}$	$DUTY^{G}$	$DUTY^{J}$	$DUTY^{O}$	$DUTY^{R}$	$DUTY^{U}$			
Statistical discrepancy		QX^{B}	QX^{C}	QX^{G}	QX^{J}	QX^{O}	QX^{R}	QX^{U}	QX^{B}	QX^{C}	QX^{G}	QX^{J}	QX^{O}	QX^{R}	QX^{U}			
Value-added(VA*)		VA^{B}	VA^{C}	VA^{G}	VA^{J}	VA^{O}	VA^{R}	VA^{U}										
Total Inputs		X^{B}	X^{C}	X^{G}	X^{J}	X^{O}	X^{R}	X^{U}										

BRZ: Brazil
CHN: China
IND: India
JPN: Japan
EUR25: 25 countries of EU
RUS: Russia
USA: United States of America

***FD** is composed of 4 categories;
1. Private Consumption (**CP**),
2. Government Consumption (**CG**),
3. Investment Demand (**I**),
4. Inventory (**IV**).

***VA** is composed of 4 categories;
1. Wages (**WAGE**),
2. Operating Surplus (**SUR**),
3. Depreciation of Fixed Capital (**DEP**),
4. Indirect Tax less Subsidy (**TAX**)

[Source: Institute of Developing Economies, JETRO, *the 2005 BRICs international input-output table*]

3. Model

Our model is named as Multi-Country/Multi-Sector Model (hereafter MCMS in abbreviation). MCMS model is a single-period static model determining the individual country's sectoral prices and total outputs simultaneously. The estimation of parameters is based on a calibration[2] .

Assumption 1: Country and Sector

It is supposed to have *r* countries (or regions), each having *n* sectors. The BRICs international input-output in 2005 which we utilize includes Brazil. Russia, India, China, EU25, United States, and Japan (i.e. r=7). Sectors are composed of 7 sectors (i.e. n=7).

Assumption 2: Homogenously and Differentiated Oligopolistic Market

The homogenous oligopoly market is introduced into individual domestic commodity market. In domestic market, although firms compete with each other, there is a limitation of variety produced for the domestic market. In contrast, the world total market becomes differentiated market because plural commodities with different prices are sold. They compete with each other for product differentiation in the international market. Also, firms don't enter/exit in response to economic profit and loss.

3.1 Determination Sectoral Output

Total sectoral output in each country is assumed to determine sectoral demand, i.e. intermediate and final demand. This is corresponding to each column of international input-output table.

$$XX_i^h = \sum_k^r \sum_j^n xv_{ij}^{hk} + \sum_k^r CP_i^{hk} + \sum_k^r CG_i^{hk} + \sum_k^r I_i^{hk} + \sum_k^r IV_i^{hk} + \sum_k^r SD_i^{hk} + EX_i^h + Q_i^h \quad (1)$$

XX_i^h : Total output in the h-th country's the i-th sector
xv_{ij}^{hk} : Intermediate input from the h-th country's the i-th sector to the k-th country's the j-th sector
CP_i^{hk} : Household consumption in the k-th country of the commodity coming from h-th country's the i-th sector
CG_i^{hk} : Government consumption in the k-th country of commodity coming from the h-th country's the i-th sector
I_i^{hk} : Investment in the k-th country of the commodity coming from the h-th country's the i-th sector
IV_i^{hk} : Inventories in the k-th country of the commodity coming from the h-th country's the i-th sector
SD_i^{hk} : National account balancing item
EX_i^h : Export for the h-th country's the i-th commodity
Q_i^h : Statistical discrepancy for the h-th country's the i-th commodity

We endogenize xv_{ij}^{hk} and CP_i^{hk}which seem to be important facts in economic activity.

[2] See Appendix A.

3.2 Household's Behavior

3.2.1 Determination of Consumption Demand Function

In the representative consumer approach, an aggregate utility function is used. We assume love of variety for household, in other words, differentiated products. The amount of variety for each commodity is assumed to be *m*. Under this assumption, household attempts to behave the maximization of his utility by considering varieties.

$$\underset{CP_{vi}^{hk}}{\text{maximization}} \qquad U^k = \left[\sum_v^m \sum_h^r \sum_i^n \alpha_{vi}^{hkC} \left(CP_{vi}^{hk}\right)^{\frac{\sigma_c^k - 1}{\sigma_c^k}}\right]^{\frac{\sigma_c^k}{\sigma_c^k - 1}} \tag{2}$$

$$\text{subjetc to} \qquad Y^k = \sum_v^m \sum_h^r \sum_i^n \left(1 + \tau_i^{hkT}\right)\left(1 + \tau_i^{kC}\right) p_{vi}^h CP_{vi}^{hk} \tag{3}$$

U^k : Utility of the *k*-th country

Y^k : Disposable income of the *k*-th country

CP_{vi}^{hk} : *k*-th country's household consumption of the *i*-th sector commodity produced by *v*-th firm in *h*-th country

τ_i^{kC} : Consumption tax on the *k*-th country's the *i*-th commodity

p_{vi}^h : Sectoral price of commodity which is sold by *v*-th firm in *h*-th country

α_{vi}^{hkC} : CES utility-weighting parameter for CP_{vi}^{hk} for each consumer

σ_c^k : CES utility elasticity of substitution

We use the Lagrangian multiplier method for solving the constrained utility maximization problem. Lagrangian function is defined as follows:

$$L_v^{kC} = \left[\sum_v^m \sum_h^r \sum_i^n \alpha_{vi}^{hkC} \left(CP_{vi}^{hk}\right)^{\frac{\sigma_c^k - 1}{\sigma_c^k}}\right]^{\frac{\sigma_c^k}{\sigma_c^k - 1}} + \lambda_v^{kC}\left[Y^k - \sum_v^m \sum_h^r \sum_i^n \left(1 + \tau_i^{hkT}\right)\left(1 + \tau_i^{kC}\right) p_{vi}^h CP_{vi}^{hk}\right] \tag{4}$$

where λ_v^{kC} is the Lagrangian multiplier of the *k*-th country's *v*-th commodity. The first-order conditions are given by:

$$\frac{\partial L_v^{kC}}{\partial CP_{vi}^{hk}} = 0 \qquad CP_{vi}^{hk} = \left[\frac{\alpha_{vi}^{hkC}}{\lambda_v^{kC}\left(1 + \tau_i^{hkT}\right)\left(1 + \tau_i^{kC}\right) p_{vi}^h}\right]^{\sigma_c^k} U^k \tag{5}$$

$$\frac{\partial L_v^{kC}}{\partial \lambda_v^{kC}} = 0 \qquad Y^k = \sum_v^m \sum_h^r \sum_i^n \left(1 + \tau_i^{hkT}\right)\left(1 + \tau_i^{kC}\right) p_{vi}^h CP_{vi}^{hk} \tag{6}$$

Substituting the equation (5) into (2), we obtain the following equation.

$$\lambda_v^{kC} = \left[\sum_v^m \sum_h^r \sum_i^n \frac{\left(\alpha_{vi}^{hkC}\right)^{\sigma_c^k}}{\left[\left(1+\tau_i^{hkT}\right)\left(1+\tau_i^{kC}\right)p_{vi}^h\right]^{\sigma_c^k-1}}\right]^{-\frac{1}{1-\sigma_c^k}} \tag{7}$$

Then, substituting equations (5) and (7) into (6) yield the marginal utility. As the marginal utility is underlying the demand price, we put it as P_{vi}^{kC}.

$$\frac{Y^k}{U^k} = P_v^{kC} = \left[\sum_v^m \sum_h^r \sum_i^n \frac{\left(\alpha_{vi}^{hkC}\right)^{\sigma_c^k}}{\left[\left(1+\tau_i^{hkT}\right)\left(1+\tau_i^{kC}\right)p_{vi}^h\right]^{\sigma_c^k-1}}\right]^{\frac{1}{1-\sigma_c^k}} \tag{8}$$

We can see the relation by the equations (7) and (8) as,

$$P_v^{kC} = \frac{1}{\lambda_v^{kC}} \tag{9}$$

In addition, we can define the indirect utility function as:

$$U^k = \frac{Y^k}{P_v^{kC}} \tag{10}$$

Combining equations (5), (9) and (10), the consumption demand function is derived.

$$CP_{vi}^{hk} = \frac{\left(\alpha_{vi}^{hkC}\right)^{\sigma_c^k} Y^k}{\left[\left(1+\tau_i^{hkT}\right)\left(1+\tau_i^{kC}\right)p_{vi}^h\right]^{\sigma_c^k}\left(P_v^{kC}\right)^{1-\sigma_c^k}} \tag{11}$$

where we obtain the consumer function. Furthermore, we consider homogeneous oligopoly where arbitrary v=1,2,….,m is regarded as follows:

$$p_{vi}^k = p_i^k \tag{12}$$

$$CP_{vi}^{hk} = CP_i^{hk} \tag{13}$$

Substituting (12) into (8), we obtain the following equation:

$$P^{kC} = \left(m_i^h\right)^{\frac{1}{1-\sigma_c^k}} \left[\sum_h^r \sum_i^n \frac{\left(\alpha_i^{hkC}\right)^{\sigma_c^k}}{\left[\left(1+\tau_i^{hkT}\right)\left(1+\tau_i^{kC}\right)p_i^h\right]^{\sigma_c^k-1}}\right]^{\frac{1}{1-\sigma_c^k}} \tag{14}$$

In addition, substituting equation (12) and (13) into equation (11) yields consumption function as:

$$CP_{vi}^{hk} = \frac{\left(\alpha_{vi}^{hkC}\right)^{\sigma_c^k}}{m_i^h[(1+\tau_i^{hkT})(1+\tau_i^{kC})p_{vi}^h]^{\sigma_c^k}\left[\sum_h^r \sum_i^n (\alpha_i^{hkC})^{\sigma_c^k}[(1+\tau_i^{hkT})(1+\tau_i^{kC})p_i^h]^{1-\sigma_c^k}\right]} Y^k \tag{15}$$

Now, we assume the case of Cobb-Douglas utility; $\sigma_c^k = 1$;

$$CP_i^{hk} = \frac{\alpha_i^{hkC}}{m_i^h\left(1+\tau_i^{hkT}\right)\left(1+\tau_i^{kC}\right)p_i^h} Y^k$$
$$\sum_h^r \sum_i^n \alpha_i^{hkC} = 1 \tag{16}$$

The equation (16) is applied to our model as the consumption function.

3.3 Disposable income

The household's disposable income in the *k*-th country is defined by total wage as,

$$Y^k = \sum_j^n w_j^k L_j^k \tag{17}$$

3.4 Wage rate

We explain the sectoral wage rate by the productivity of labor.

$$w_j^k = \beta_j^k \left(\frac{XX_j^k}{L_j^k}\right) \tag{18}$$

3.5 Producer's Behavior

3.5.1 Determine of Intermediate Demand and Factor Demand

The productive activity by firms is based on using intermediate inputs and primary factors of production, including labors. This is captured in a constant elasticity of substitution CES function shown as,

$$\underset{L_j^k,\ xv_{ij}^{hk}}{\text{minimization}} \quad C_j^k = \left[\left(1+\tau_j^{kF}\right)w_j^k\, L_j^k + \sum_h^r \sum_i^n \left(1+\tau_i^{hkT}\right)\left(1+\tau_{ij}^{kI}\right)p_i^h xv_{ij}^{hk}\right] \tag{19}$$

$$\text{subjetc to} \quad XX_j^k = \left[\alpha_j^{kF}\left(L_j^k\right)^{\frac{\sigma_w^k-1}{\sigma_w^k}} + \sum_h^r \sum_i^n \alpha_{ij}^{hkI}\left(xv_{ij}^{hk}\right)^{\frac{\sigma_w^k-1}{\sigma_w^k}}\right]^{\frac{\sigma_w^k}{\sigma_w^k-1}} \tag{20}$$

C_j^k : Cost function of k-th country's the j-th sector
w_j^k : Wage rate of the k-th country's the j-th sector
L_j^k : Labor of the k-th country's the j-th sector
τ_j^{kF} : Factor (labor) tax rate on the k-th country's the i-th sector
τ_j^{kI} : Factor (intermediate production) tax rate on the k-th country's the i-th sector
α_j^{kF} : CES factor weighting parameter for the primary factor endowment
α_{ij}^{hkI} : CES factor weighting parameter for the intermediate input
σ_w^k : CES elasticity of substitution between the primary factor endowment and the intermediate input

We use the Lagrangian multiplier method for solving the constrained cost minimization problem. Lagrangian function is defined as follows:

$$L_j^{kX} = \left[(1+\tau_j^{kF})w_j^k\, L_j^k + \textstyle\sum_h^r \sum_i^n (1+\tau_i^{hkT})(1+\tau_{ij}^{kI})p_i^h xv_{ij}^{hk}\right]$$
$$+\lambda_j^{kX}\left[XK_j^k - \left[\alpha_j^{kF}\left(L_j^k\right)^{\frac{\sigma_w^k-1}{\sigma_w^k}} + \textstyle\sum_h^r \sum_i^n \alpha_{ij}^{hkI}\left(xv_{ij}^{hk}\right)^{\frac{\sigma_w^k-1}{\sigma_w^k}}\right]^{\frac{\sigma_w^k}{\sigma_w^k-1}}\right] \quad (21)$$

where λ_j^{kX} is the Lagrange multiplier of i-th industry of the k-th country. The first-order conditions for this optimization are:

$$\frac{\partial L_j^{kX}}{\partial L_j^k} = 0 \qquad L_j^k = \left[\frac{\lambda_j^{kX}\alpha_j^{kF}}{(1+\tau_j^{kF})w_j^k}\right]^{\sigma_w^k} XX_j^k \quad (22)$$

$$\frac{\partial L_j^{kX}}{\partial xv_{ij}^{hk}} = 0 \qquad xv_{ij}^{hk} = \left[\frac{\lambda_j^{kX}\alpha_{ij}^{hkI}}{(1+\tau_i^{hkT})(1+\tau_{ij}^{kI})p_i^h}\right]^{\sigma_w^k} XX_j^k \quad (23)$$

$$\frac{\partial L_j^{kX}}{\partial \lambda_j^{kX}} = 0 \qquad XX_j^k = \left[\alpha_j^{kF}\left(L_j^k\right)^{\frac{\sigma_w^k-1}{\sigma_w^k}} + \sum_h^r \sum_i^n \alpha_{ij}^{hkI}\left(xv_{ij}^{hk}\right)^{\frac{\sigma_w^k-1}{\sigma_w^k}}\right]^{\frac{\sigma_w^k}{\sigma_w^k-1}} \quad (24)$$

Substituting equations (22) and (23) into (19) is represented as:

$$\lambda_j^{kX} = \left[\left(\alpha_j^{kF}\right)^{\sigma_w^k}\left[(1+\tau_j^{kF})w_j^k\right]^{1-\sigma_w^k} + \sum_h^r \sum_i^n \left(\alpha_{ij}^{hkI}\right)^{\sigma_w^k}\left[(1+\tau_i^{hkT})(1+\tau_{ij}^{kI})p_i^h\right]^{1-\sigma_w^k}\right]^{\frac{1}{1-\sigma_w^k}} \quad (25)$$

where we obtain the Lagrangian multiplier. In addition, substituting equation (22), (23) and (25) into the objective function (19) and arranging them, the unit cost function of the j-th sector in the k-th country is driven.

$$\frac{C_j^k}{XX_j^k} = c_j^k = \left[\left(\alpha_j^{kF}\right)^{\sigma_w^k}\left[(1+\tau_j^{kF})w_j^k\right]^{1-\sigma_w^k} + \sum_h^r \sum_i^n \left(\alpha_{ij}^{hkI}\right)^{\sigma_w^k}\left[(1+\tau_i^{hkT})(1+\tau_{ij}^{kI})p_i^h\right]^{1-\sigma_w^k}\right]^{\frac{1}{1-\sigma_w^k}} \quad (26)$$

The cost function is homogenous of degree one with respect to the production level. Since cost is also independent of the level of production, unit cost also equals marginal cost $c_j^k = MC_j^k$. Applying the Shephard's lemma, the differential with respect to each factor price leads to drive the conditional unit factor demand for each input factor.

$$ax_{ij}^{hk} = \frac{\partial c_j^k}{\partial\left(1+\tau_{ij}^{kI}\right)p_i^h} = \left[\frac{c_j^k \alpha_{ij}^{hkI}}{\left(1+\tau_i^{hkT}\right)\left(1+\tau_{ij}^{kI}\right)p_i^h}\right]^{\sigma_w^k} \tag{27}$$

$$bx_j^k = \frac{\partial c_j^k}{\partial\left[\left(1+\tau_j^{kF}\right)w_j^k\right]} = \left[\frac{c_j^k \alpha_j^{kF}}{\left(1+\tau_j^{kF}\right)w_j^k}\right]^{\sigma_w^k} \tag{28}$$

a_{ij}^{hk} : Unit input of commodity the h-th country's the i-th sector required to produce one unit output of the k-th country's the j-th sector.

b_j^k : Unit input of the factor production of the k-th country's the j-th sector required to produce one unit output of the k-th country's the j-th sector.

In addition, we can derive the demand function of intermediate and labor from (27) and (28).

$$xv_{ij}^{hk} = ax_{ij}^{hk} XX_j^k = \left[\frac{c_j^k \alpha_{ij}^{hkI}}{\left(1+\tau_{ij}^{kI}\right)p_i^h}\right]^{\sigma_w^k} XX_j^k \tag{29}$$

$$L_j^k = bx_j^k XX_j^k = \left[\frac{c_j^k \alpha_j^{kF}}{\left(1+\tau_j^{kF}\right)w_j^k}\right]^{\sigma_w^k} XX_j^k \tag{30}$$

3.5.2 Determination of Price under Oligopoly Market

Each firm attempts to maximize its profit. The production under homothetic technology is assumed. Profit maximization problem of the firm of the j-th sector in the k-th country is written as:

$$\pi_j^k = p_j^k XX_{vj}^k - \left(1+\tau_j^{kX}\right)C_j^k \tag{31}$$

π_j^k : Profit of the j-th sector's industry in the k-th country

τ_j^{kX} : Production tax rate on the commodity in the k-th country's j-th sector industry

The first-order condition for this problem is given as:

$$\frac{\partial \pi_j^k}{\partial p_j^k} = p_j^k\left(1+\frac{XX_j^k}{p_j^k}\frac{\partial p_j^k}{\partial XX_j^k}\right) = \left(1+\tau_j^{kX}\right)\frac{\partial C_j^k}{\partial XX_j^k} \tag{32}$$

Here, some terms equation (321) is rewritten to marginal cost and elasticity as follows:

$$MC_j^k = \frac{\partial C_j^k}{\partial XX_j^k} \tag{33}$$

$$\varepsilon_j^k = -\frac{\partial XX_j^k}{\partial p_j^k}\frac{p_j^k}{XX_j^k} \tag{34}$$

MC_j^k : Marginal cost of the j-th sector's industry in the k-th country

ε_j^k : Price elasticity of demand of the j-th sector's industry in the k-th country

Furthermore, we rewrite equation (32) by denoting μ_{vi}^h and MC_{vj}^k explicitly and price determination is defined as,

$$p_j^k = \left(1 + \tau_j^{kX}\right)\left(\frac{\tilde{\varepsilon}_j^k}{\tilde{\varepsilon}_j^k - 1}\right) MC_j^k \tag{35}$$

Here, since $\tilde{\varepsilon}_j^k$ is regarded as the price elasticity of demand for producers.

3.5.3 Determination of the Number of Firms.

Generally, the condition of market clearing is assumed, namely, the condition of profit-zero. Oligopolies have some market power, which implies that it enable producers to make some profit. It is supposed that the profit equals to real profit. We put the operating surplus which is included in value added of input-output table[3] as follows:

$$\sum_v^m \pi_{vj}^k = \sum_v^m p_{vj}^k XX_{vj}^k - \left(1 + \tau_j^{kX}\right) C_{vj}^k = SUR_j^k \tag{36}$$

π_{vj}^k : Profit of the j-th sector's v-th firm in the k-th country

XX_{vj}^k : Total production of the j-th sector's v-th firm in the k-th country

C_{vj}^k : Total cost of the j-th sector's v-th firm in the k-th country

SUR_j^k : Operating surplus of the j-th industry in the k-th country

We assume that each sectoral firm in each country is homogenous. Equation (36) is denoted as:

$$m_j^k \left[p_j^k XX_j^k - \left(1 + \tau_j^{kX}\right) C_j^k\right] = SUR_j^k \tag{37}$$

Substituting equation (35) into (36) and arranging terms lead to the determination of the number of firms as follows:

$$m_j^k = \frac{\varepsilon_j^k SUR_j^k}{p_j^k XX_j^k} \tag{38}$$

The number of firm under oligopoly market is derived, which enables to measure the degree of the market structure. If the number of competitors is small, it means that market in this sector tends to have a strong market power. In contrast, if the number of firms is large, the market power decreases.

4. Scenario Simulation

This model is a multi-sector, multiregional general equilibriums model for analyzing the economy of BRIC countries in 2005. The oligopolistic market is incorporated into this framework. The number of firm is endogenized derived and theoretically. In order to exam

[3] Show the block of value added in figure 1.

the reliability and validity of the model performance, we conduct a scenario simulation of by using this model.

4.1 Scenario

We consider a scenario in which Japan adopts an increase in consumption tax from 5 percent to 8 percent and see how the economic activity in other countries as well as in the domestic changes. Therefore, the scenario is summarized as followings,

- **Baseline**: Business as usual. The consumption tax of all sectors in Japan remains 5 percent.
- **Scenario**: The Japan's consumption tax of all sectors sets 8 percent.

Economy is based on 2005. We conduct above two simulations and compare with those results.

4.2 Results

Table 4 shows the impact of an increase of the Japan's consumption tax on the total output. It is shown that total output of Japan declines nearly 10 percent. The spillover by the domestic policy in Japan reaches to other trading partners' economy as well as domestic one. Pushing down Japan's economy makes negative effects on China, EU25 and Russia. In particular, China has the most negative influence. In contrast, it reports positive values in Brazil, India and US. Table 5 illustrates the detailed result of impacts on the sectoral output in each country.

Table 3 Percentage Deviation[4] of Total Output from Baseline

(Unit: percentage)

Brazil	China	EU25	India	Japan	Russia	US
1.00	–0.70	–0.37	0.40	–9.62	–0.32	0.15

[4] Percentage deviation is calculated as (Scenario-Baseline)*100/Baseline

Table 4 Percentage Deviation of Sectpral Output from Baseline

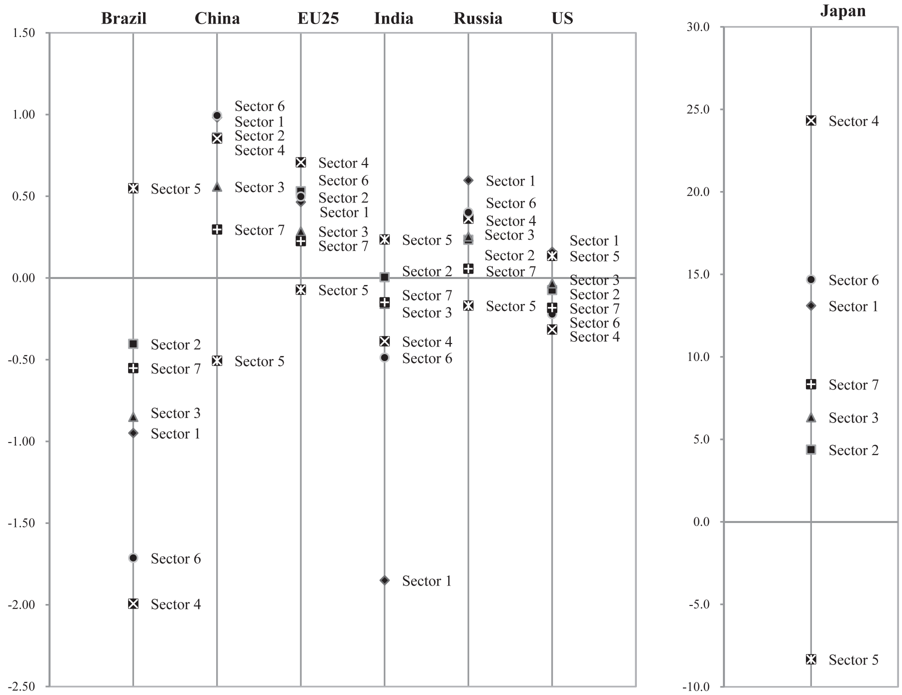
(Unit: percentage)

Economy	Sector	An increase of consumption tax from 5% to 8%	Economy	Sector	An increase of consumption tax from 5% to 8%
Brazil	Sector 1	0.931	Japan	Sector 1	−10.969
	Sector 2	0.417		Sector 2	−4.438
	Sector 3	0.953		Sector 3	−7.444
	Sector 4	1.784		Sector 4	−16.932
	Sector 5	0.123		Sector 5	−1.641
	Sector 6	1.640		Sector 6	−13.260
	Sector 7	0.912		Sector 7	−10.899
China	Sector 1	−0.942	Russia	Sector 1	−0.606
	Sector 2	−0.845		Sector 2	−0.354
	Sector 3	−0.758		Sector 3	−0.334
	Sector 4	−0.831		Sector 4	−0.357
	Sector 5	−0.050		Sector 5	−0.046
	Sector 6	−0.961		Sector 6	−0.437
	Sector 7	−0.526		Sector 7	−0.173
EU25	Sector 1	−0.471	United States	Sector 1	−0.170
	Sector 2	−0.482		Sector 2	0.070
	Sector 3	−0.380		Sector 3	0.019
	Sector 4	−0.639		Sector 4	0.268
	Sector 5	−0.084		Sector 5	0.026
	Sector 6	−0.534		Sector 6	0.204
	Sector 7	−0.336		Sector 7	0.217
India	Sector 1	1.610			
	Sector 2	−0.088			
	Sector 3	0.202			
	Sector 4	0.380			
	Sector 5	0.033			
	Sector 6	0.466			
	Sector 7	0.287			

Figure 1 illustrates percentage change of the number of firms from baseline in respectively regions. The number of firms is an index that measures the degree of the market competitiveness. Increases above zero indicate a decrease of the market power and an increase of the market competitiveness. In contrast, decreases below zero in this index indicate an intensity of the market power and a weakness of the market competitiveness.

The right hand side of figure 1 shows the market condition of Japan. All sectors except the industry of construction (sector 5) show positive. It reports that market condition tends to be competitive. The results would tell that the downward shift of consumption demand stimulates the market to be more competitive by reducing prices, i.e. the firm will have to lower price in order to increase sales. This phenomenon also corresponds to China, EU25, and Russia which show the negative impact in Table 4. In contrast, the results of Brazil, India and US which denote the positive in Table 4 are reverse. The reason would be considered that Japan's consumers will alter theirs behaviors and purchase a foreign commodity (produced by firm in Brazil, India or US) with lower price alternatively. Japan's demand increase for the commodity produced by other countries will drive the intensity of market power. In particular, it can guess that, since the productive firms which have an ability to export to Japan tends to be limited in the market, the demand increase promotes the market power to be more stronger.

Figure 2 Percentage Change of the Number of Firms from Baseline



The increase of the consumption tax is expected to give major damage to economic growth in Japan. The government of Japan currently plans to one more tax increase from 8 percent to 10 percent 2015 depending on the economic condition. Japan might face more serious economic stagnation.

5. Conclusion

We constructed a Multi-Country/Multi-Sector model (MCMS) which incorporated the imperfect competition structure of oligopolistic market by using the BRICs international input-output table in 2005. We assumed homogeneous and differentiated oligopoly market in that homogeneous products are produced in individual domestic commodity market while differentiated products manufactured by the firm in each country are sold with different prices in the international market.

By incorporating oligopolistic market, our model can describe the reality of the strategic interaction among firms. Along with this, since the number of sectoral firms in each country is derived theoretically, we can analyze the change of the market aspect by some economic impacts. In addition, each economic activity is formulated without relying on the assumption of Armington, which implies that elements of arbitrariness in a model are eliminated as much as possible. Thus, our study realized to build the economic model based on the imperfect competition without distorting the basic framework of international input-output table.

However, there are some improvements to be required in future study. First, we should reconsider the measurement of the market structure. Although we can say that deriving the number of firms theoretically from the framework of input-output model was the innovative trial, we would be required to refine the formula for the number of firms referring to the results of the scenario simulation. Also, the index of the number of firms seems to be an unsatisfactory index unless firms are symmetric (or homogeneous). In order to analyze more detailed, the index in consideration of market share and the distribution of firms would be better as the concentration ratio or Herfindahl-Hirschman Index (HHI). Second, other economic factors should be incorporated as the transportation or exchange rate in order to reflect the economic reality. If the exchange rate is introduced into the whole model, there is a possibility to be modified by linking the international financial model. These improvements will enable to develop more sophisticated economic systems for analyzing today's complex international economy.

Appendix A. Calibration

A time period of this model is only one year. Therefore, the method calibration is applied to estimate the parameters. Here, we note the formula of calibration.

Consumption

The parameter in equation (16) is estimated as follows:

$$\alpha_i^{hkC} = \frac{m_i^h\left(1+\tau_i^{kC}\right)p_i^h\left(\frac{e^k}{e^h}\right)CPK_i^{hk}}{YK^k} \tag{39}$$

Wage Rate

The parameter in equation (18) is estimated as follows:

$$\beta_j^k = w_j^k\left(\frac{L_j^k}{XX_j^k}\right) \tag{40}$$

Unit input of commodity

The parameter in equation (27) is estimated as follows:

$$\alpha_{ij}^{hkI} = \frac{\left(1+\tau_i^{hkT}\right)\left(1+\tau_{ij}^{kI}\right)p_i^h\left(\frac{e^k}{e^h}\right)\left(ak_{ij}^{hk}\right)^{\frac{1}{\sigma_w^k}}}{c_j^k} \tag{41}$$

Unit input of the factor production

The parameter in equation (28) is estimated as follows:

$$\alpha_j^{kF} = \frac{\left(1+\tau_j^{kF}\right)w_j^k\left(bk_j^k\right)^{\frac{1}{\sigma_w^k}}}{c_j^k} \tag{42}$$

Appendix B. Deriving Process of the Price Elasticity of Demand

In this section, we show the process for deriving price elasticity of demand ε_j^k. The partial derivatives in the elasticity of demand is shown as:

$$\varepsilon_j^k = -\frac{\partial XX_j^k}{\partial p_j^k} \Big/ \frac{p_j^k}{XX_j^k}$$
$$= -\frac{\partial\left(\sum_l^r \sum_q^n xv_{jq}^{kl} + \sum_l^r CP_j^{kl} + \sum_l^r CG_j^{kl} + \sum_l^r I_j^{kl} + \sum_l^r IV_j^{kl} + EX_j^{kl} + SD_j^k + Q_j^k\right)}{\partial p_j^k} \frac{p_j^k}{XX_j^k} \tag{43}$$

Rearranging (43) yields the following equation.

$$\varepsilon_j^k = -\frac{\partial\left(\sum_l^r \sum_q^n xv_{jq}^{kl}\right)}{\partial p_j^k} \frac{p_j^k}{XX_j^k} - \frac{\partial\left(\sum_l^r CP_j^{kl}\right)}{\partial p_j^k} \frac{p_j^k}{XX_j^k} \tag{44}$$

As you see, the each index of the both sides of equation (44) is evaluated with exchanging *h* with *k* and replacing *i* by *j*. Then, each term on the left side is alternatively expressed as follows:

$$\varepsilon_j^k = \varepsilon_j^{kXV} + \varepsilon_j^{kCP} \tag{45}$$

(i) Evaluation of ε_j^{kXV}

At first, we consider only price elasticity of intermediate demand of equation (45).

$$\varepsilon_j^{kXV} = -\frac{\partial\left(\sum_l^r \sum_q^n xv_{jq}^{kl}\right)}{\partial p_j^k} \frac{p_j^k}{XX_j^k} \tag{46}$$

Here, we restate the intermediate demand.

$$xv_{ij}^{hk} = \left[\frac{c_j^k \alpha_{ij}^{hkI}}{\left(1+\tau_i^{hkT}\right)\left(1+\tau_{ij}^{kI}\right)p_i^h}\right]^{\sigma_w^k} XX_j^k \tag{29}$$

The each index of the both sides of equation (29) is evaluated with exchanging *h* with *k* and replacing *i* by *j* as follows:

$$xv_{jq}^{kl} = \left[\frac{c_q^l \alpha_{jq}^{klI}}{\left(1+\tau_j^{klT}\right)\left(1+\tau_{jq}^{lI}\right)p_j^k}\right]^{\sigma_w^k} XX_q^l \tag{47}$$

Substituting equation (47) into (46) leads to equation (48).

$$\varepsilon_j^{kXV} = -\frac{\partial\left[\sum_l^r \sum_q^n \left(c_q^l\right)^{\sigma_w^k} \left(\alpha_{jq}^{klI}\right)^{\sigma_w^k} \left[\left(1+\tau_{jq}^{lI}\right)\right]^{-\sigma_w^k} \left(p_j^k\right)^{-\sigma_w^k} XX_q^l\right]}{\partial p_j^k} \frac{p_j^k}{XX_j^k} \tag{48}$$

In addition, we note unit cost c_q^l of (48) below.

$$c_q^l = \left[\left(\alpha_q^{lF}\right)^{\sigma_w^k} \left[\left(1+\tau_q^{lF}\right) w_q^l\right]^{1-\sigma_w^k} + \sum_k^r \sum_j^n \left(\alpha_{jq}^{klI}\right)^{\sigma_w^k} \left[\left(1+\tau_j^{klT}\right)\left(1+\tau_{jq}^{lI}\right) p_j^k\right]^{1-\sigma_w^k} \right]^{\frac{1}{1-\sigma_w^k}} \tag{26}$$

Taking into consideration (26), we calculate (47) and rearrange as follows,

$$\varepsilon_j^{kXV} = \frac{\sigma_w^k \left(p_j^k\right)^{-\sigma_w^k}}{XX_j^k} \left[\sum_l^r \sum_q^n \left(c_q^l\right)^{\sigma_w^k} \left(\alpha_{jq}^{klI}\right)^{\sigma_w^k} \left[\left(1+\tau_{jq}^{lI}\right)\right]^{-\sigma_w^k} XX_q^l - \left(p_j^k\right)^{-\sigma_w^k+1} \sum_l^r \sum_q^n \left(c_q^l\right)^{\frac{2\sigma_w^k-1}{\sigma_w^k}} \left(\alpha_{jq}^{klI}\right)^{2\sigma_w^k} XX_q^l \left[\left(1+\tau_{jq}^{lI}\right)\right]^{1-2\sigma_w^k} \right] \tag{49}$$

As you see, equation of (49) has a mechanism which absorbs economic impacts from sectoral firms in foreign countries as well as ones in domestic. It would enable to sufficiently analyze the complicated international economy.

(ii) Evaluation of ε_j^{kCP}

Next, we consider the price elasticity of consumption demand.

$$\varepsilon_j^{kCP} = -\frac{\partial\left(\sum_l^r CP_j^{kl}\right)}{\partial p_j^k} \frac{p_j^k}{XX_j^k} \tag{50}$$

Here, we restate consumption demand function of equation (16).

$$CP_i^{hk} = \frac{\alpha_i^{hkC}}{m_i^h \left(1+\tau_i^{hkT}\right)\left(1+\tau_i^{kC}\right) p_i^h} Y^k \tag{16}$$

We evaluate the index of the equation (16) with exchanging *h* with *k* and replacing *i* by *j*.

$$CP_j^{kl} = \frac{\alpha_j^{klC}}{m_j^k \left(1+\tau_j^{klT}\right)\left(1+\tau_j^{lC}\right) p_j^k} Y^l \tag{51}$$

Partial derivaites of bothe side of (51) is shown as:

$$\varepsilon_j^{kCP} = -\frac{\partial\left(\sum_l^r \alpha_j^{klC} \left(m_j^k\right)^{-1} \left[\left(1+\tau_j^{klT}\right)\left(1+\tau_j^{lC}\right) p_j^k\right]^{-1} Y^l\right)}{\partial p_j^k} \frac{p_j^k}{XX_j^k} \tag{52}$$

We calculate (52) and rearrange as follows,

$$\varepsilon_j^{kCP} = \frac{\sum_l^r \alpha_j^{klC} \left[\left(1+\tau_j^{klT}\right)\left(1+\tau_j^{lC}\right)\right]^{-1} Y^l}{p_j^k XX_j^k m_j^k} \tag{53}$$

As equation (45) shows, price Elasticity of Demand is shown by (49) and (53) as,

$$\varepsilon_j^k = \varepsilon_j^{kXV} + \varepsilon_j^{kCP}$$

$$\varepsilon_j^k = \frac{\sigma_w^k\left(p_j^k\right)^{-\sigma_w^k}}{XX_j^k}\left[\sum_l^r \sum_q^n \left(c_q^l\right)^{\sigma_w^k}\left(\alpha_{jq}^{klI}\right)^{\sigma_w^k}\left[\left(1+\tau_{jq}^{lI}\right)\right]^{-\sigma_w^k} XX_q^l - \left(p_j^k\right)^{-\sigma_w^k+1} \sum_l^r \sum_q^n \left(c_q^l\right)^{\frac{2\sigma_w^k-1}{\sigma_w^k}}\left(\alpha_{jq}^{klI}\right)^{2\sigma_w^k} XX_q^l\left[\left(1+\tau_{jq}^{lI}\right)\right]^{1-2\sigma_w^k}\right] + \frac{\sum_l^r \alpha_j^{klC}\left[\left(1+\tau_j^{klT}\right)\left(1+\tau_j^{lC}\right)\right]^{-1} Y^l}{p_j^k XX_j^k m_j^k} \quad (54)$$

Appendix C. Variables

C.1. Endogenous variables

XX_i^h	Total output in the h-th country's the i-th sector
xv_{ij}^{hk}	Intermediate input from the h-th country's the i-th sector to the k-th country's the j-th sector
CP_i^{hk}	Household consumption in the k-th country of a commodity coming from h-th country's the i-th sector
CG_i^{hk}	Government consumption in the k-th country of commodity coming from the h-th country's the i-th sector
I_i^{hk}	Investment in the k-th country of the commodity coming from the h-th country's the i-th sector
IV_i^{hk}	Inventories in the k-th country of the commodity coming from the h-th country's the i-th sector
SD_i^{hk}	National account balancing item
EX_i^h	Export for the h-th country's the i-th commodity
Q_i^h	Statistical discrepancy for the h-th country's the i-th commodity
U^k	Utility of the k-th country
Y^k	Disposable income of the k-th country
CP_{vi}^{hk}	k-th country's household consumption of the i-th sector commodity produced by v-th firm in h-th country
p_{vi}^h	Sectoral price of commodity which is sold by v-th firm in h-th country
C_j^k	Cost function of k-th country's the j-th sector
w_j^k	Wage of the k-th country's the j-th sector
L_j^k	Labor of the k-th country's the j-th sector
a_{ij}^{hk}	Total input of commodity the h-th country's the i-th sector required to produce one unit output of the k-th country's the j-th sector
b_j^k	Total input of the factor production of the k-th country's the j-th sector required to produce one unit output of the k-th country's the j-th sector
π_j^k	Profit of the j-th sector's industry in the k-th country
MC_j^k	Marginal cost of the j-th sector's industry in the k-th country
ε_j^k	Price elasticity of all demand of the j-th sector's industry in the k-th country
ε_j^{kCP}	Price elasticity of consumption demand of the j-th sector's industry in the k-th country
ε_j^{kXV}	Price elasticity of intermediate demand of the j-th sector's industry in the k-th country
π_{vj}^k	Profit of the j-th sector's v-th firm in the k-th country
XX_{vj}^k	Total production of the j-th sector's v-th firm in the k-th country
C_{vj}^k	Total cost of the j-th sector's v-th firm in the k-th country
SUR_j^k	Operating surplus of the j-th industry in the k-th country

C.2. Exogenous variables

τ_j^{kF}	Factor (labor) tax rate on the k-th country's the i-th sector
τ_j^{kI}	Factor (intermediate production) tax rate on the k-th country's the i-th sector
τ_i^{kC}	Consumption tax on the k-th country's the i-th commodity
τ_i^{hX}	Production tax rate on the commodity in the h-th country's i-th sector
$\tilde{\varepsilon}_j^k$	Price elasticity of demand for producers.

C.3. Parameters

α_{vi}^{hkC}		CES utility-weighting parameter for CP_{vi}^{hk} for each consumer
α_{ij}^{hkI}		CES factor weighting parameter for the intermediate input
α_j^{kF}		CES factor weighting parameter for the primary factor endowment
σ_w^k		CES elasticity of substitution between the primary factor endowment and the intermediate input
σ_c^k	2.0	Factor tax rate on the k-th country's the i-th sector
σ_w^k	2.0	Production tax rate on the commodity in the h-th country's i-th sector

References

Dixit, A.K. and J.E. Stiglitz (1977), Monopolistic Competition and Optimum Product Diversity, *American Economic Review,* Vol. 67, No. 3, pp. 297-308.

Bernard, A.B., J. Eaton, J.B. Jensen and S. Kortum. (2003), Plants and Productivity in International Trade, *American Economic Review,* Vol.93, No.4, pp. 1268-1290.

Feenstra, R.C. (2004), *Advanced International Trade: Theory and Evidence*, Princeton University Press.

Helpman, E, M.J. Melitz and S.R. Yeaple (2004), Export Versus FDI with Heterogeneous Firms, *American Economic Review,* Vol. 94, No. 1, pp. 300-316.

Kosaka, H (1994), *Model Analysis on the Global System,* Yuhikaku, Tokyo [in Japanese]

Kosaka, H (2011), Multi-Country and Multi-Sector Modeling for the World Economy, *Global Security Research Institute Working Papers*, No. 29.

Institute of Developing Economies, JETRO, the 2005 BRICs international input-output table, http://www.ide.go.jp/Japanese/Publish/Books/Tokei/material.html.

Krugman, P (1979), Increasing Returns, Monopolistic Competition and International Trade, *Journal of International Economics*, Vol. 9, No. 4, pp. 469–479.

Krugman, P (1980), Scale Economies, Product Differentiation, and the Pattern of Trade, *American Economic Review*, Vol. 70, No. 5, pp. 950–959.

Krugman, P (1981), Intraindustry Specialization and the Gains from Trade, *Journal of Political Economy*, Vol. 89, No.5, pp. 959–974.

Krugman, P and M. Obstfeld (2005), *International Economics: Theory and Policy*, Addison-Wesley Educational Publishers Inc.

Melitz, M.J. (2003), The Impact of Trade on Intra-Industry Reallocation and Aggregate Industry Productivity, *Econometrica*, Vol. 71, No.6, pp. 1695–1725.

Neary, J.P. (2009), International Trade and General Oligopolistic Equilibrium, *University of Oxford*.

The Effect of Abandoning Nuclear Power on the Japanese Economy

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Abstract

After Fukushima nuclear power disaster, it became a big issue whether we should continue to use nuclear power or not. This issue should be considered not only economical view point but also national security, social welfare, environment etc. To discuss this problem more precisely, we will show the result of economic simulation by our model "Japan Inter-industry Dynamic Econometric Analysis (JIDEA)" about the effect of abandoning nuclear power on the Japanese economy.

The model JIDEA is based on the historical data from 1990 to 2010 and made a base line simulation from 2011 until 2030 following the historical trend of Japanese economy. Against this base line, we made the alternative simulation on the structural change of electricity, namely the nuclear power totally replaced by fossil fuel power from 2014 until 2030 and named it "Nuclear power zero case". Comparing with the base line, Nuclear power zero case shows that in 2030, GDP decreases by 1.7% (-77 billion Yen) against the base line level, import of fossil fuel and natural gas increase by 18.5%, diffusion of carbon dioxide increases by 74.5%.

Keywords: environment, JIDEA, nuclear power, national security, simulation.

1. The assumption of the simulation

The main assumption of simulation is summarized in following column. On the base line, we assume that Japanese economy continues to keep the nuclear power even after Fukushima disaster in 2013 until 2030. The Nuclear zero assumption is to replace all nuclear power to fossil fuel power. In our model, the electricity sector is expressed by one column but three separate electricity columns such as fossil fuel power, nuclear power and renewable energy in detailed I-O table are available. Accordingly, we can calculate how much effect will be when the whole amount of electricity by nuclear power is replaced by fossil fuel power after 2014 until 2030. In fact, Japanese nuclear power stations have been all stopped after 2014 because of Fukushima disaster and adding to this the stoppage for periodical inspection of the nuclear station. After Fukushima disaster, the Nuclear Regulation Authority (NRA) was reorganized, and Nuclear power regulation is to be revised. Only after NRA authorizes the security of the plant, the nuclear station can be reactivated. Thus the reactivation of Japanese nuclear power is getting hard not only by the regulation change but also by the increase of political dispute among many political groups and by the opposition of neighbouring citizen of the power station. In future adding to these

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old plants reactivation, other 2 new plants are planned to be constructed.

Base line assumption of JIDEA Model

- Recent year (2011-2013) simulation result is overloaded by actual or provisional data published by the government.
- For the electricity sector, break-off of nuclear power by Fukushima disaster or by the periodical inspection are not included.
- The reconstruction budget (2014-2015) for the Great East Japan Earthquake is included.
- The programmed increase of consumer tax in 2014 and 2015 is included.
- The intermediate input coefficient matrix is extended by historical trend.

The main exogenous variables

- The population forecasted by the National Institute of Population and Social Securities Research is adopted.
- The labor participation rate and labor productivity are extended by historical trend.
- The exchange rate is fixed by 2013 annual average rate.
- The foreign demand and import price are supplied by BTM[*1] forecast adjusted by recent trade situation.
- The government investment is extended by one year lagged value

[*1] Bilateral Trade Model is maintained by INFORUM
(The structure of JIDEA model is explained at http://www.iti.or.jp/jidea.htm and refer also http://www.inforum.umd.edu/)

From 2011 to 2013, actually the nuclear power was gradually replaced to fossil fuel power but detail data on this transition period are not available, hence for the baseline we assumed that the electricity is supplied continuously with the nuclear power. In the nuclear power zero case, the Japanese import of fuels should increase but we assumed the world supply of fuels is abundant and the price of fuels does not increase because of the increase of Japanese fuel import.

Abandoning the nuclear power, the renewable energy utilization (water, solar, wind, geothermal, biomass, etc.) will also increase but the actual ratio of these energy sources in Japan are relatively small, so, we assume these energy sources will continue to increase by low level.

For the replacement of Nuclear power with fossil fuel power, we assume the fossil fuel power stations have enough capacity, accordingly no new investment is required or no conversion cost is needed. We did not take into consideration the decommission cost of nuclear power or retreatment and the keeping cost of nuclear ashes.

2. The effect of abandoning nuclear power on the Japanese economy

Since the end of 2012, Prime minister Abe's new economic policy, "Abenomics" has been making good effects on the Japanese economy such as stock market or foreign exchange rate. But the additional policy to promote industrial development has not been performed so far. The future Japanese economy is still in obscure.

Japanese population passed its peak in 2008 and now is taking the route of decreasing. The competition in the overseas market is heating up so seriously that Japanese industry tends to invest more to overseas not to inland. These reasons forced Japanese economy low growth rate of production and of investment.

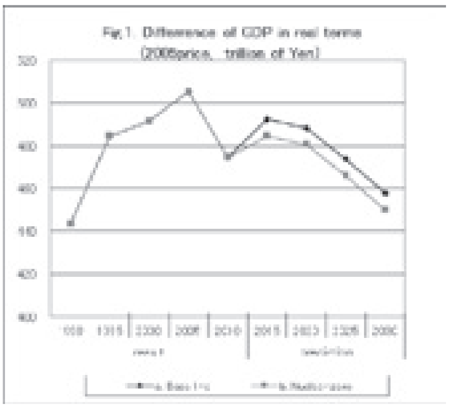
Under these circumstances, how much effect on Japanese economy will be by abandoning nuclear power? Assuming that the replacement of nuclear power with fossil fuel power starts from 2014, GDP decreases by 1.7% (-7.7 billion Yen) from the base line in the year of 2030. The annual growth rate of GDP 2010 to 2030 is -0.18% on the Base line but it declines to -0.27% on the nuclear power zero case, (Table1. Fig. 1).

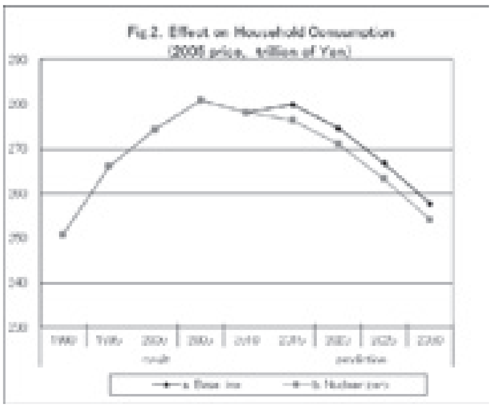
The household consumption in real term decreases by 1.4% (-3.6 trillion of Yen) from the base line in 2030. At the same time the consumption of electricity decreases by 22.5% (Table2 and Fig. 2). The main reason of decrease in household consumption is the shrink down of per capita disposable income in real term which will reach 2.42 million Yen in 2030 but 2.38 million Yen in case of Nuclear zero. It means 1.9% decrease (Table3, Fig. 3). The cause of shrinking disposable income comes from the increase of electricity price,

Table 1 Differrence of GDP in real terms (2005 price, trillion of Yen)

	result					prediction				difference in 2030 (%)	2010-30 average growth rate%
	1990	1995	2000	2005	2010	2015	2020	2025	2030		
a. Base line	443.5	484.5	491.4	505.3	474.6	492.3	488.2	473.7	457.7	−1.69	−0.18
b. Nuclear zero	443.5	484.5	491.4	505.3	474.6	484.5	480.4	465.9	450.0		−0.27
difference(b−a)	0.0	0.0	0.0	0.0	0.0	−7.8	−7.8	−7.8	−7.8		−0.09

(Data source; JIDEA model data base and its prediction)





(Data source; JIDEA model data base and its prediction) which affects whole industry to shrink down their production.

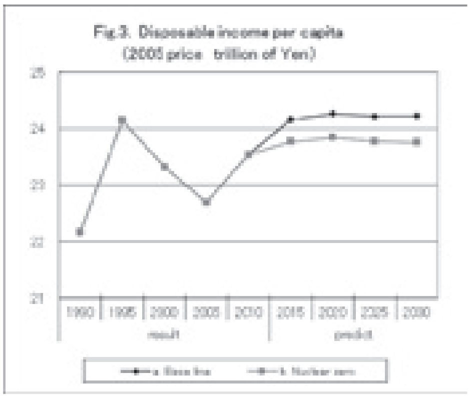
The difference of household electricity consumption between Base line and Nuclear zero case gets smaller from 1.3 trillion Yen in 2015 to 1.1 trillion Yen in 2030, of which cause is the price of electricity is much higher in case of Nuclear zero (Table2).

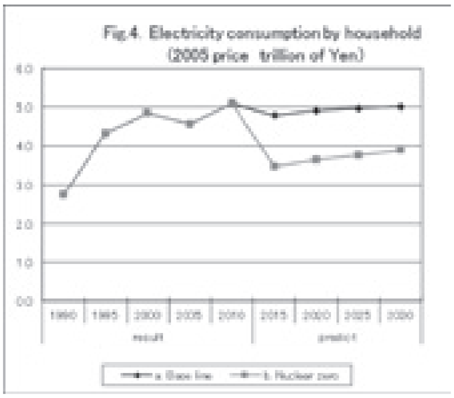
Table 2 Effect on Household Consumption (2005 price, trillion of Yen)

		result					prediction				difference in 2030 (%)	2010-30 average growth rate%
		1990	1995	2000	2005	2010	2015	2020	2025	2030		
Consumption total	a. Base line	250.7	266.1	274.3	280.9	278.1	279.9	274.5	266.8	257.7	−1.39	−0.38
	b. Nuclear zero	250.7	266.1	274.3	280.9	278.1	276.3	271.0	263.2	254.1		−0.45
	difference(b−a)	0.0	0.0	0.0	0.0	0.0	−3.6	−3.6	−3.6	−3.6		−0.07
Consumption Electricity (in real)	a. Base line	2.7	4.3	4.8	4.6	5.1	4.8	4.9	5.0	5.0	−22.50	−0.08
	b. Nuclear zero	2.7	4.3	4.8	4.6	5.1	3.5	3.6	3.8	3.9		−1.35
	difference(b−a)	0.0	0.0	0.0	0.0	0.0	−1.3	−1.3	−1.2	−1.1		−1.27
consumption Electricity (in nominal)	a. Base line	3.5	4.5	4.8	4.6	5.2	5.3	5.4	5.5	5.6	5.88	0.37
	b. Nuclear zero	3.5	4.5	4.8	4.6	5.2	5.1	5.4	5.7	5.9		0.66
	difference(b−a)	0.0	0.0	0.0	0.0	0.0	−19.1	−0.7	15.3	33.0		0.29
Consumer price of electricity	a. Base line	1.29	1.05	0.99	1.00	1.02	1.10	1.10	1.11	1.12	−21.40	0.30
	b. Nuclear zero	1.29	1.05	0.99	1.00	1.02	1.47	1.49	1.51	1.53		−0.90

Table 3 The effect on disposable income per capita (2005 price million of Yen)

		result					prediction				difference in 2030 (%)	2010-30 average growth rate%
		1990	1995	2000	2005	2010	2015	2020	2025	2030		
Disposable income in real	a. Base line	2.22	2.41	2.33	2.27	2.35	2.42	2.43	2.42	2.42	−1.92	0.14
	b. Nuclear zero	2.22	2.41	2.33	2.27	2.35	2.38	2.38	2.38	2.38		0.05
	difference(b−a)	0.0	0.0	0.0	0.0	0.0	−3.96	−4.15	−4.39	−4.66		−0.10
Disposable income in nominal	a. Base line	2.18	2.44	2.38	2.27	2.34	2.47	2.54	2.59	2.66	−0.27	0.64
	b. Nuclear zero	2.18	2.44	2.38	2.27	2.34	2.46	2.53	2.58	2.65		0.63
	difference(b−a)	0.0	0.0	0.0	0.0	0.0	−0.68	−0.69	−0.70	−0.73		−0.01





The effect of nuclear zero case on GDP (-1.7%) is lower than on household consumption (-1.4%). It indicates that the influence on industry is much more than on household. The share of electricity consumption in household against total consumption is 1.8% in 2010 and it increases a little to 1.9% in 2030.

The diminution of electricity demand is caused by price of electricity. Since we assume that the fuel import price does not change, the cause of the price increase owes to the conversion of nuclear power to fuel. In fact, there is a possibility that some part of nuclear power may be replaced by renewable energy but the portion of renewable energy in total electricity is relatively small (7.6%, of which 90% consists of water power). It is difficult to estimate how much the ratio of renewable energy utilization increases. Therefore we assume it same as the historical trend. In fact the ratio is increasing so rapidly in recent year that our assumption based on long term trend may be underestimated.

When the nuclear power is replaced by fossil fuel power, the demand for fuel should be increase. The fuel supply of Japan relies almost on foreign countries and import of fuel in 2030 increases by 18.5% from the base line. But Japanese total import increases only by 1.8%. The share of fuel import in 2030 is 12% but the share in 2010 was 17%, so the share itself decreases. That is the reason why increase in total import is relatively small.

In the Nuclear power zero case, nuclear fuel import should also be zero but the share of nuclear fuel demand in Japan is so small (0.052%) that we don't take it into consideration.

Under these conditions, Table 5. shows how much the Nuclear zero case affects to the prices? The domestic demand price of electricity increases by 36.4% in 2030 comparing with the base line but consumer price increases only by 1.4%. The annual average increase of consumer price in the Base line from 2010 to 2030 is relatively low (0.66%) but in the case of nuclear zero it goes up to 0.73%. As we indicate above, we assume the import price

Table 4 The effect on import (2005 price trillion of Yen)

		result					prediction				difference in 2030 (%)	2010-30 average growth rate%
		1990	1995	2000	2005	2010	2015	2020	2025	2030		
Total	a. Base	46.1	55.6	62.8	72.5	73.8	83.9	89.1	92.6	95.9	1.82	1.31
	b. Alt	46.1	55.6	62.8	72.5	73.8	85.5	90.7	94.3	97.6		1.41
	b–a	0.0	0.0	0.0	0.0	0.0	1.6	1.7	1.7	1.7		0.09
Commodity	a. Base	21.8	28.9	35.6	44.0	47.1	55.5	60.1	63.3	66.3	−0.48	1.72
	b. Alt	21.8	28.9	35.6	44.0	47.1	55.2	59.8	63.0	65.9		1.70
	b–a	0.0	0.0	0.0	0.0	0.0	−0.3	−0.3	−0.3	−0.3		−0.02
Service	a. Base	9.2	9.2	9.7	10.8	10.3	11.8	12.4	13.1	13.7	−0.74	1.44
	b. Alt	9.2	9.2	9.7	10.8	10.3	11.7	12.4	13.0	13.6		1.41
	b–a	0.0	0.0	0.0	0.0	0.0	−0.1	−0.1	−0.1	−0.1		−0.04
Fuel	a. Base	10.9	13.4	13.2	13.5	12.6	12.6	12.4	12.1	11.8	18.54	−0.34
	b. Alt	10.9	13.4	13.2	13.5	12.6	14.6	14.5	14.2	14.0		0.52
	b–a	0.0	0.0	0.0	0.0	0.0	2.0	2.1	2.1	2.2		0.85
Share of fuel import	a. Base	23.7	24.1	21.1	18.7	17.1	15.0	14.0	13.1	12.3	16.42	
	b. Alt	23.7	24.1	21.1	18.7	17.1	17.0	16.0	15.1	14.3		

Remarks; a. Base means "the base line", b. Alt means "Nuclear zero case".

of fuel does not change in both case and Japan does not export or import any electricity, accordingly the electricity price of domestic demand is almost equal to the producer's price. The annual average increase of domestic demand price from 2010 to 2030 is 0.45% on the base line and it goes up to 2.02% in Nuclear zero case.

Changes in intermediate coefficients caused by replacement of nuclear power to fossil fuel power introduces complicated effects on the production of all other industries. Firstly, the change in input materials to produce electricity affects the production of their supplying industry. Adding to this, the change of combination of input materials increases the price of electricity. The electricity is the basic materials required by all industries and its price increase affects the price of all other industries. The consequence of price increase is that all industries should readjust their demand for their input materials. These ripple effects are causes of the changes in production amount (Table 6).

In the Nuclear power zero case, the shift to the fossil fuel power makes the production

Table 5 The effect on Prices (Base 2005)

		result					prediction				difference in 2030 (%)	2010-30 average growth rate%	
		1990	1995	2000	2005	2010	2015	2020	2025	2030		%	b−a
CPI	a. Base	0.941	1.007	1.023	1.000	0.996	1.055	1.091	1.111	1.136	1.41	0.66	0.07
	b. Alt	0.941	1.007	1.023	1.000	0.996	1.068	1.104	1.125	1.152		0.73	
GDP deflator	a. Base	1.006	1.044	1.054	1.000	0.982	0.995	1.010	1.027	1.050	1.52	0.34	0.08
	b. Alt	1.006	1.044	1.054	1.000	0.982	1.009	1.025	1.042	1.066		0.41	
Total import price	a. Base	0.995	0.785	0.862	1.000	1.015	1.090	1.133	1.175	1.215	1.65	0.90	0.08
	b. Alt	0.995	0.785	0.862	1.000	1.015	1.105	1.150	1.193	1.235		0.99	
Fuel import price	a. Base	0.647	0.365	0.584	1.000	1.292	1.697	1.819	1.936	2.048	0.00	2.33	0.00
	b. Alt	0.647	0.365	0.584	1.000	1.292	1.697	1.819	1.936	2.048		2.33	
Electricity domestic	a. Base	1.286	1.046	0.989	1.000	1.021	1.098	1.098	1.106	1.117	36.44	0.45	1.57
	b. Alt	1.286	1.046	0.989	1.000	1.021	1.466	1.479	1.501	1.524		2.02	
Electricity producing	a. Base	1.286	1.046	0.989	1.000	1.021	1.098	1.098	1.106	1.117	36.44	0.45	1.57
	b. Alt	1.286	1.046	0.989	1.000	1.021	1.465	1.479	1.501	1.524		2.02	

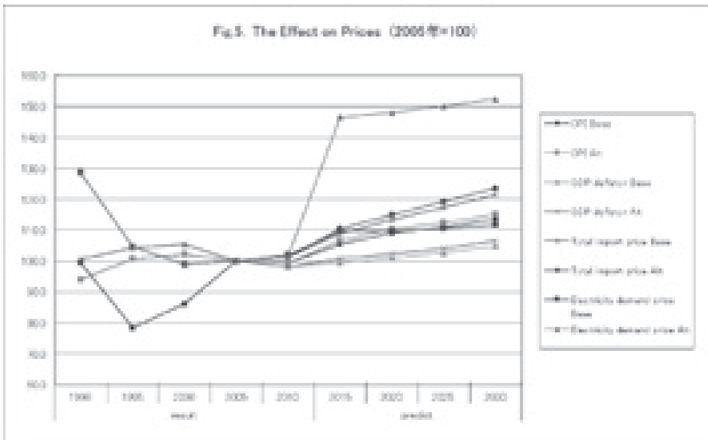


Table 6 The effect on Production (2005 price, Trillion of Yen)

		result					prediction				2030 deviation ratio %	2010-2030 percentage contrbution to increse	2030 electricity input ratio %
		1990	1995	2000	2005	2010	2015	2020	2025	2030			
Total industries	a. Base	846.820	906.017	921.936	961.620	890.517	939.677	948.200	938.974	931.385	−1.17	−100.0	2.8
	b. Alt	846.820	906.017	921.936	961.620	890.517	929.078	937.667	928.278	920.476			3.6
Agriculture, fishery, etc.	a. Base	14.591	14.018	13.080	12.287	11.739	11.468	11.189	10.877	10.606	−1.58	−1.5	1.8
	b. Alt	14.591	14.018	13.080	12.287	11.739	11.326	11.044	10.721	10.438			2.4
Mining	a. Base	1.818	1.310	1.300	1.008	0.738	0.608	0.528	0.429	0.335	4.78	0.1	2.0
	b. Alt	1.818	1.310	1.300	1.008	0.738	0.622	0.543	0.444	0.351			2.7
Manufacturing total	a. Base	301.226	301.306	294.210	304.682	285.637	299.554	293.036	280.657	270.090	− 0.94	−23.2	2.3
	b. Alt	301.226	301.306	294.210	304.682	285.637	296.756	290.415	278.091	267.561			2.9
Food, beverage	a. Base	37.222	39.521	37.624	35.889	35.052	34.315	33.038	31.580	30.309	−2.21	− 6.1	2.3
	b. Alt	37.222	39.521	37.624	35.889	35.052	33.729	32.447	30.951	29.639			3.1
Textile	a. Base	13.358	9.571	6.981	4.375	3.098	2.445	1.989	1.652	1.387	−1.15	− 0.1	2.3
	b. Alt	13.358	9.571	6.981	4.375	3.098	2.413	1.964	1.633	1.371			3.0
Wood, pulp, furniture	a. Base	17.214	16.796	14.688	12.830	10.318	9.770	9.186	8.492	7.904	−1.39	−1.0	6.6
	b. Alt	17.214	16.796	14.688	12.830	10.318	9.642	9.068	8.379	7.794			7.3
Chemicals	a. Base	22.681	24.238	26.395	27.487	27.471	28.557	29.089	29.069	29.207	− 0.60	−1.6	1.8
	b. Alt	22.681	24.238	26.395	27.487	27.471	28.382	28.920	28.897	29.031			2.0
Petro & coal Prod.	a. Base	14.018	17.624	17.233	16.920	16.041	15.727	15.242	14.553	13.926	1.95	2.5	3.1
	b. Alt	14.018	17.624	17.233	16.920	16.041	15.993	15.516	14.825	14.197			4.0
Rubber, Plastics	a. Base	13.352	13.180	13.407	13.636	12.006	12.353	12.152	11.633	11.189	− 0.93	−1.0	4.9
	b. Alt	13.352	13.180	13.407	13.636	12.006	12.239	12.043	11.526	11.085			6.2
Glass, cement, etc.	a. Base	9.589	8.758	8.151	7.156	5.622	5.889	5.934	5.691	5.425	− 0.72	− 0.4	3.3
	b. Alt	9.589	8.758	8.151	7.156	5.622	5.845	5.893	5.651	5.386			4.1
Iron & steel	a. Base	26.681	27.112	24.056	25.314	23.779	25.304	24.466	22.997	21.732	− 0.78	−1.5	3.2
	b. Alt	26.681	27.112	24.056	25.314	23.779	25.087	24.271	22.816	21.563			4.2
Non-ferrous metal	a. Base	7.470	7.141	7.574	7.330	7.002	6.557	6.176	5.610	5.105	−1.10	− 0.5	3.0
	b. Alt	7.470	7.141	7.574	7.330	7.002	6.482	6.109	5.548	5.049			4.0
Metal prod.	a. Base	20.491	21.124	17.722	16.363	12.831	13.312	12.818	11.892	10.994	−1.36	−1.4	1.5
	b. Alt	20.491	21.124	17.722	16.363	12.831	13.130	12.651	11.734	10.844			2.1
General Machine, etc.	a. Base	23.664	20.145	20.003	22.501	18.528	23.579	23.240	22.276	21.373	− 0.96	−1.9	1.4
	b. Alt	23.664	20.145	20.003	22.501	18.528	23.316	23.005	22.057	21.167			1.9
Electric Machines	a. Base	31.018	37.553	42.044	47.054	51.168	52.119	51.255	49.335	47.701	− 0.96	− 4.2	1.5
	b. Alt	31.018	37.553	42.044	47.054	51.168	51.539	50.729	48.845	47.245			2.0
Transportation equip.	a. Base	45.450	41.495	42.266	53.016	48.908	54.875	54.192	52.435	51.156	− 0.65	−3.1	2.2
	b. Alt	45.450	41.495	42.266	53.016	48.908	54.576	53.888	52.119	50.821			2.9
Precision equip.	a. Base	4.168	3.783	3.761	3.723	3.434	3.568	3.449	3.288	3.131	− 0.96	− 0.3	2.4
	b. Alt	4.168	3.783	3.761	3.723	3.434	3.530	3.415	3.256	3.101			3.2
Other Manufact.	a. Base	14.850	13.266	12.306	11.088	10.377	11.186	10.810	10.153	9.551	−2.96	−2.6	2.5
	b. Alt	14.850	13.266	12.306	11.088	10.377	10.853	10.496	9.855	9.268			3.0
Service total	a. Base	529.187	589.382	613.345	643.642	592.406	628.049	643.448	647.013	650.354	−1.26	−75.4	3.3
	b. Alt	529.187	589.382	613.345	643.642	592.406	620.374	635.665	639.021	642.128			4.3
Construction	a. Base	97.365	87.864	78.445	63.237	48.941	48.085	49.331	47.119	43.985	− 0.89	−3.6	3.2
	b. Alt	97.365	87.864	78.445	63.237	48.941	47.665	48.923	46.719	43.593			3.2
Electricity	a. Base	11.203	15.361	17.439	15.783	15.964	16.561	17.085	17.307	17.556	−7.74	−12.4	1.8
	b. Alt	11.203	15.361	17.439	15.783	15.964	15.017	15.592	15.874	16.198			2.2
Gass	a. Base	1.521	2.034	2.462	2.894	2.873	3.033	3.087	3.101	3.108	− 0.61	− 0.2	12.5
	b. Alt	1.521	2.034	2.462	2.894	2.873	3.018	3.071	3.084	3.089			16.0
Water, sewage	a. Base	7.549	7.691	7.862	8.306	7.430	7.912	8.062	8.003	7.959	−1.66	−1.2	5.7
	b. Alt	7.549	7.691	7.862	8.306	7.430	7.806	7.948	7.881	7.827			7.5
Commerce	a. Base	80.611	93.884	94.193	106.709	92.022	96.330	93.735	89.717	85.786	−1.71	−13.4	0.8
	b. Alt	80.611	93.884	94.193	106.709	92.022	94.829	92.263	88.248	84.323			1.0
Finance	a. Base	28.579	33.939	35.650	41.587	35.249	37.338	37.721	37.404	36.968	−1.05	−3.6	9.1
	b. Alt	28.579	33.939	35.650	41.587	35.249	36.977	37.357	37.028	36.578			11.8
Real estate	a. Base	56.141	62.848	64.794	66.206	68.516	69.892	68.786	66.814	64.416	− 0.71	− 4,2	3.4
	b. Alt	56.141	62.848	64.794	66.206	68.516	69.514	68.384	66.385	63.961			4.5
Transportation equip.	a. Base	39.692	41.733	38.206	40.784	38.683	39.593	39.002	37.625	36.264	− 0.74	−2.4	2.3
	b. Alt	39.692	41.733	38.206	40.784	38.683	39.318	38.734	37.357	35.997			3.1
Communication	a. Base	8.452	10.328	19.509	20.037	22.047	25.790	28.694	31.242	33.763	− 0.89	−2.8	1.5
	b. Alt	8.452	10.328	19.509	20.037	22.047	25.608	28.479	30.987	33.461			2.1
Information	a. Base	13.127	13.248	20.445	25.899	27.776	32.649	36.227	39.601	43.316	−1.16	− 4.6	4.5
	b. Alt	13.127	13.248	20.445	25.899	27.776	32.288	35.832	39.157	42.813			5.9
Government service	a. Base	19.794	31.307	34.465	38.536	26.307	28.481	28.934	28.488	27.832	− 4.36	−11.1	8.6
	b. Alt	19.794	31.307	34.465	38.536	26.307	27.253	27.713	27.269	26.618			11.2
Education, Research	a. Base	31.148	35.308	35.347	36.292	32.007	32.975	32.750	31.871	31.099	− 0.64	−1.8	4.0
	b. Alt	31.148	35.308	35.347	36.292	32.007	32.761	32.544	31.669	30.900			5.2
Medical and health care	a. Base	28.207	41.853	42.214	50.211	54.013	59.977	63.774	66.491	69.032	0.02	0.1	0.8
	b. Alt	28.207	41.853	42.214	50.211	54.013	60.023	63.807	66.514	69.044			1.1
Other public	a. Base	4.158	4.479	4.010	5.031	4.529	4.658	4.755	4.838	4.922	− 0.24	− 0.1	0.5
	b. Alt	4.158	4.479	4.010	5.031	4.529	4.647	4.744	4.827	4.910			0.7
Business service	a. Base	42.354	46.207	55.348	64.617	63.047	73.044	81.551	89.385	98.292	−1.48	−13.3	2.3
	b. Alt	42.354	46.207	55.348	64.617	63.047	71.993	80.395	88.094	96.841			3.0
Personal service	a. Base	51.921	53.543	56.643	52.022	47.881	46.854	45.515	44.039	42.501	− 0.08	− 0.3	3.9
	b. Alt	51.921	53.543	56.643	52.022	47.881	46.841	45.494	44.010	42.465			5.1
N.E.C.	a. Base	7.365	7.755	6.313	5.491	5.121	4.877	4.439	3.968	3.555	−1.27	− 0.4	0.6
	b. Alt	7.365	7.755	6.313	5.491	5.121	4.816	4.385	3.918	3.510			0.7

Remarks: JIDEA model has 73 sectors and in this table, we aggregated them into 34 sectors.

of mining and of petro-coal product increase rapidly and the medical-health care sector slightly increases but all other rest of the industries decrease their production (Table 6).

Looking at Table 6, the deviation is wider in total service industry (-1.26%) than manufacturing industry (-0.94%). But it should be noted that total service industry contains electricity sector which has the largest deviation ratio in whole industries. If the electricity sector is exempted, the deviation ratio of service industry is -1.09%.

It may appear strange that the deviation of medical and health care service has plus sign instead of minus, that is to say, the production of this sector increases after abandoning the nuclear power. The reason of this phenomenon explains that the price of this sector is determined by public authority and not affected market mechanism and even if the prices of other sectors has increased, the price of this sector stays same not affected by electricity cost, accordingly relative price of this sector decreases and the demand of this sector increase.

To examine more precisely the effect on the sectorial production, calculating the difference of production in 2010 and 2030 sector by sector and again calculate the difference of this difference between the base line and the Nuclear zero case. Dividing this second difference by total of this second difference, we name this ratio as "Percentage contribution to increase" (Table 6).

The percentage contribution to increase amounts are all minus except mining, petro & coal product and medical & health care because of the increase of electricity price. To see more detailed effect on production by each sector, putting the sectors in order of absolute value of "the percentage contribution to increase". Then the order, that is to say, the order of affected sectors are as follows; commerce, business service, electricity, government service, food & beverage, information, electrical equipment, real estate, construction, finance, transportation equipment, communication, other manufacturing, petro & coal products, transportation service, general machines, education & research, chemicals, iron & steel, agriculture & fishing, etc.

The employment also decreases because of the production decrease. In 2030 employment in the Nuclear zero case is 118 thousand less than in the base line, it means 0.18% decrease. In manufacturing industry, it decreases 37 thousand (-0.44%) and the total service sector decreases 27 thousand (-0.05%). In the electricity sector, we assume that conversion from the nuclear power to fossil fuel power goes rapidly and smoothly, the employment affected is very small (Table 7).

Following the decrease in production and employment, the labor productivity of total industry in 2030 decreases by 0.99%, the manufacturing industry decreases by 0.5% and service industry by 1.2% (Table 8). The decrease of labor productivity in the electricity sector is relatively high. It is 7.7%.

Finally, how is the effect of abandoning nuclear power on environment? The fossil fuel power increase causes the augmentation of carbon-dioxide emission. We have already made a report on "the Prediction of CO2 emission up to 2020 in Japanese economic activities[1]" at INFORUM world conference (2010) held at Hikone in Japan. Applying same method, we estimate the emission of CO2 from the electricity industry, and compare the amount of CO2 by the base line and by the Nuclear zero case. Abandoning nuclear power and converting it to the fossil fuel power, CO2 emission increase by 1.646 thousand ton (74.6%) in 2030.

1 http://www.inforum.umd.edu/papers/conferences/2010/JIDEA_CO2.pdf

Table 7 The effect on Employment (Thousand)

		result					prediction				difference in 2030 (%)	2010-30 average growth rate%	
		1990	1995	2000	2005	2010	2015	2020	2025	2030		%	b–a
Total	a. Base	65,821	68,547	68,249	66,701	65,662	65,817	65,555	64,981	64,398	−0.18	−0.10	−0.01
	b. Alt	65,821	68,547	68,249	66,701	65,662	65,699	65,440	64,865	64,280		−0.11	
	b–a	0.0	0.0	0.0	0.0	0.0	−11.8	−11.5	−11.6	−11.8		−0.01	
Total manufacturing	a. Base	13,654	12,541	10,800	9,816	9,663	9,456	9,112	8,703	8,328	−0.44	−0.74	−0.02
	b. Alt	13,654	12,541	10,800	9,816	9,663	9,408	9,069	8,664	8,291		−0.76	
	b–a	0.0	0.0	0.0	0.0	0.0	−4.8	−4.3	−4.0	−3.7		−0.02	
Total service	a. Base	46,415	50,144	52,104	52,020	51,210	51,766	52,062	52,105	52,087	−0.05	0.08	0.00
	b. Alt	46,415	50,144	52,104	52,020	51,210	51,744	52,038	52,080	52,061		0.08	
	b–a	0.0	0.0	0.0	0.0	0.0	−2.2	−2.4	−2.5	−2.7		0.00	
Electricity	a. Base	162	170	180	167	164	164	163	162	160	−0.07	−0.12	0.00
	b. Alt	162	170	180	167	164	164	163	162	160		−0.12	
	b–a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.00	

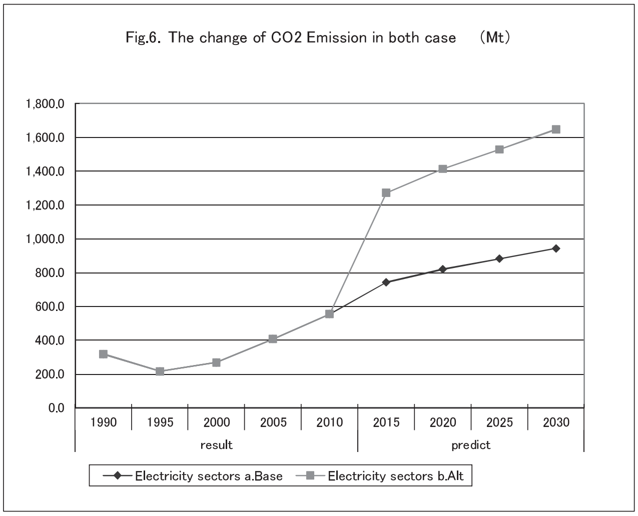
Remakes; Total contains Agriculture & fishing etc. and Mining. Total service contains Construction, Electricity, Gas, Water.

Table 8 The Effect on Labor Productivity (2005=100)

		result					prediction				difference in 2030 (%)	2010-30 average growth rate%	
		1990	1995	2000	2005	2010	2015	2020	2025	2030		%	b–a
Total	a. Base	89.2	91.7	93.7	100.0	94.1	99.0	100.3	100.2	100.3	−0.99	0.32	−0.05
	b. Alt	89.2	91.7	93.7	100.0	94.1	98.1	99.4	99.3	99.3		0.27	
Total manufacturing	a. Base	71.1	77.4	87.8	100.0	95.2	102.1	103.6	103.9	104.5	−0.50	0.46	−0.02
	b. Alt	71.1	77.4	87.8	100.0	95.2	101.6	103.2	103.4	104.0		0.44	
Total service	a. Base	92.1	95.0	95.1	100.0	93.5	98.1	99.9	100.4	100.9	−1.21	0.38	−0.06
	b. Alt	92.1	95.0	95.1	100.0	93.5	96.9	98.7	99.2	99.7		0.32	
Electricity	a. Base	73.3	95.4	102.7	100.0	102.7	106.7	110.8	113.2	115.8	−7.67	0.60	−0.40
	b. Alt	73.3	95.4	102.7	100.0	102.7	96.8	101.2	103.9	106.9		0.20	

Table 9 The change of CO2 Emission in both case (Mt)

		result					prediction				difference in 2030 (%)	2010-30 average growth rate%
		1990	1995	2000	2005	2010	2015	2020	2025	2030		
Electricity sectors	a. Base	317.6	215.4	268.3	406.2	554.6	742.8	819.9	881.4	943.5	74.6	2.7
	b. Alt	317.6	215.4	268.3	406.2	554.6	1,271.0	1,413.3	1,528.3	1,646.9		5.6
	b–a	0.0	0.0	0.0	0.0	0.0	528.1	593.4	646.8	703.4		2.9



3. Comparing with the result of other institute

In April 2013, Central Research Institute of Electric Power Industry (CRIEPI) published a report on "the outlook of industrial structure and energy situation until 2030". The report clarifies three forecasts of "standard case", "the good World economy and low Yen case" and "the stagnant World economy and high exchange rate case". CRIEPI is specialized for electric energy research, and its report follows details of effect on Fukusima disaster and thereafter actual situation of nuclear power station.

Since we are not in the position to obtain these detailed information, our forecast is based on industrial structure before Fukushima disaster, when the nuclear power covers 30% of whole electric power needed. On this base, from 2014 (actually Japanese nuclear power station all stopped) we assume that the part of nuclear power is replaced by fossil fuel power and after that year, no nuclear power station is reactivated.

The CRIEPI model is different from our model not only in the model setting as mentioned above but also in the database, the model structure and assumed conditions. These differences are summarized in the following column. Though the comparison of both results of model may be meaningless but the comparison itself arouses many different viewpoints of Japanese electric energy situation, we dare to put here the comparison table as Table 10. The case we selected for comparison is the "standard case" of CRIEPI.

Between the forecast of JIDEA and CRIEPI there are relatively wide differences in the average annual growth rate of GDP in real term or industrial production. This is because of the difference of assumption for the performance of Japanese economy or the forecast of the world economy.

The period of historical result is from 2000 to 2010 and both models should show the same value but actually they are different. These differences owe to the database adopted by each model. In JIDEA model, database is from historical I-O table and CRIPI is based mainly on the national account macro data.

In the electric price there is a big difference. JIDEA assumes that the fuel import price

Table 10 Comparison the result with CRIEPI model

	JIDEA			CRIEPI		
	2000-2010 average growth rate	2010-2030 average growth rate		2000-2010 average growth rate	2010-2030 average growth rate	
		Base line	Nuclear zero		Base line	Nuclear zero
GDP in real term	−0.35%	−0.18%	−0.27%	0.71%	1.15%	1.09%
Production by Manufacturing industry	−0.30%	−0.28%	−0.33%	−0.23%	1.21%	1.13%
Production of service industry	−0.35%	0.47%	0.40%	0.24%	1.10%	1.04%
Employment	100.0	98.1	97.9	100.0	95.2	94.8
	(2010)	(2030)	(2030)	(2010)	(2030)	(2030)
Price index of electricity	100	109.4	149.2	100	138.5	152.4
	(2010)	(2030)	(2030)	(2010)	(2030)	(2030)
Demand for electric power	−0.88%	0.48%	0.07%	0.56%	0.36%	0.30%
Emission of CO2	7.53%	2.69%	5.59%	6.27%	4.19%	10.34%
Fuel price index	100	158.1	158.0	100	233.9	233.9
	(2010)	(2030)	(2030)	(2010)	(2030)	(2030)

Table 11 Main differences of Assumption; JIDEA & CRIEPI

	JIDEA	CRIEPI
Database	1990-2010 timeseries I-O tables aggregated 73 sectors	macro data of national account, world energy market, energy statistics, local economy, electricity statistics
Model Structure	Bottom up type model based on timeseries I-O tables, estimate the component of final demand and value added sector by sector. The intermediate coefficient extended by historical trend. Import and export are estimated using the BTM prediction. The fuel sector is aggregated in one sector. For CO2 estimation, the material matrix 2010 is used for conversion of monetary base to material volume base.	Top down model using macro economic data, combining government budget with macro economy. In this main model, the sectorial industrial production and energy demand are estimated. Intermediate coefficient is extended by recent industrial situation. Regarding the energy, energy source competing model is used to analyse demand of each fuel.
Assumption for economic forecast	Per capita disposable income stays in low level because of diminishing population, increasing aged population. The export which was onece the driving force of Japanese economy, is stagnant as annual growth rate of 0.6% from 2010 to 2030 because of foreign competition and the shift of production facilities to abroad.	Instead of shrinking and aging population, activating women power, the work force will not be short. With the good world economy, export increases at the rate of 3.2% from 2010 to 2030. Increasing replacement demand makes public investment increase Helped by deduction of corporate income tax, GDP increases annualy by 1.1%.
Exchange rate	1$=96.795Yen in 2013 and fixed until 2030	1$=87.8Yen in 2010. From 2010 to 2030 annual depreciation rate is 0.1%.
Energy price (Crude oil import price)	From 2010 to 2030 estimated annual growth rate is 2.3%.	From 2010 to 2030 annual growth rate assumed 4.4%.
Nuclear power station operating ratio	The historical change from 1990 to 2010 continues its trend until 2030. For the Nuclear power zero case, from 2014 intermediate input coefficient of electricity is changed to replace nuclear power production to fossile fuel power. The fossil fuel power input coefficient does not change but keeps its historical trend.	After 2014, the nuclear power station is reactivated step by step and the stations reached to the end of service period stops its operation. The new nuclear power stations such as Shimane No.3 and Ohma start to activate. In 2030, nuclear power occupies 30% of total electricity production. In the case of Nuclear zero, after Summer of 2013 all nuclear power stations stopped. In the Nuclear zero case, the fuel structure assumes LNG : coal=1:1.
Renewable energy	Same as growth of electricity, it reaches 1.102 times of the base year level in 2030.	The solar electricity becomes 7.57 times of the base year 2010 level in 2030, the window power is 2.46 times.

increases annually by 2.3% from 2010 to 2030. CRIEPI assumes higher increase rate. The price of JIDEA is domestic demand price derived from I-O data but the price of CRIEPI is based on actual Yen/Kwh base.

The estimation of the emission of CO2 depends on many preconditions such as ratio of nuclear power, forecast of renewable energy, etc.

On the scenario of the base line, our model assumes that the nuclear station continues to work following the historical trend. In CRIEPI's estimate, it includes the plan to construct new nuclear power station and decommission of the station which reached the end of service life and it assumes that a half of them still active in 2030. Though both models assume same as the nuclear power stops from 2014, the result is different. JIDEA estimates higher influence of abandoning nuclear power on the CO2 emission.

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References

Ono M., Y. Sasai, T. Hasegawa and T. Imagawa (2010), "The prediction of CO2 emissions up to 2020 in Japanese economic activities", *JESNA*, Vol. 8, No. 1, March 2012.

Central Research Institute of Electric Power Industry (CRIEPI) (2013), "The Outlook of Industrial Structure and Energy Situation until 2030", *CRIEPI Research Report*, Y12033, April 2013

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