Identification of the Domains for Reverse Patterns of Forestry Specialization Using a Linear Trade Model that Includes Intermediate Goods

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Abstract: This paper discusses development of a multi-country, multi-commodity linear trade model that includes intermediate goods. This new model improves the author's previous model by rigidly formulating the supply and demand conditions for each good according to the final demand for that good as a linear function of gross domestic product (GDP). Parameter domains of φ_K^o (i.e., the level of public benefit - in monetary terms - provided by the forestry sector in country K, assuming that the forestry sector maintains its present output level) are investigated where the pattern of forestry specialization in each country reverses from its primary state. These domains were identified in three-dimensional φ_K^o spaces. Public benefit was assumed to be directly proportionate to the country's forestry output. Calculations were made using data from the "Asian International Input-Output Table 2000." Simulations were conducted to examine interactions between Japan, the U.S., and China. Results showed that (1) if the present public benefit from the forestry sector in each country is not considered at all, then forestry output should be decreased in Japan, (2) when public benefit is considered, a "reverse domain" (in which desirable outputs increase) certainly exists within the range of $\varphi_J^o = 0 - 1.0(10^{10}\$/\text{year})$ in the three-dimensional φ_K^o spaces, and (3) when the agriculture, forestry,

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and fishery sectors are aggregated into one sector and public benefits from these sectors are evaluated together, this "reverse domain" exists within the range of $\varphi_J^o = 0 - 70(10^{10}\$/\text{year})$ in the same spaces.

1. Introduction

If a country were to attempt to increase the rate of self-sufficiency for its forestry sector or primary industry, the public benefits provided by these sectors should be internalized into trade models. That is, if one were to meaningfully analyze the extent to which evaluation of these public benefits reverses the specialization pattern of these sectors, it would be necessary to construct a trade model with a good command of actual international input-output data.

Although the Ricardian model is simple, it provides a good explanation of the mechanisms of international trade. In recent years, there have been many attempts to augment this model to formulate a multi-country, multi-commodity model or a model including intermediate goods, but none of these efforts have included adequate command of international input-output data (Jones and Kenen, 2002). I devised such a model in a previous study (Ejiri, 2005) to compensate for abandoning price changes. The distinctive feature of this model is that it combines the Ricardian model and input-output data, thus making an analysis that includes intermediate goods possible. However, the model is unable to rigidly formulate the supply and demand conditions for each good in the world market. It allows a gap between supply and demand, and shows the degree of this gap in the parameter values. The disadvantage of this method is that the pattern of specialization suggested by the optimal solution depends largely on the parameter values.

The model presented in this paper addresses the parameter dependence problem. The model's chief advantage is that the supply and demand conditions for each good are rigidly formulated according to the domestic final demand for that good as a linear function of the country's gross domestic product (GDP) (Ejiri, 1997). Naturally, the intermediate demand for a good is determined automatically by the output of that good. The previous model was only applied to Japan and the U.S., but the improved model is also applied to China. As in the previous study, barriers to trade, including transport costs and tariffs, are ignored.

2. Background

2.1. Basic implications of the Ricardian model

The Ricardian model predicts trade profit by looking at the difference in relative labor productivity between sectors across countries (Kimura, 2000, Koizumi and Aihara, 1981, Komiya and Amano, 1979, Watanabe, 1991). Table 1 shows parameter values in a two-country, two-commodity schematic Ricardian model. Table 1(1) and 1(2) indicates the output and allocated labor force at the primary stage. (Values are hypothetical.) Table 1(3) shows the average labor productivity calculated from these values. These labor productivities are assumed to be constant. Table 1(4) shows gains in world output when Japan specializes in the production of cloth and the U.S. in wheat. This table also shows world trade can lead to profit for each country, even when all sectors in one country (here it is Japan) are inferior to another (here it is the U.S.) with respect to absolute labor productivity.

Figure 1 illustrates the essential concept of the Ricardian model. Figures 1(1), 1(2), 1(3) show the production possibility frontiers of Japan, the U.S., and the world, respectively, in the case of Table 1 (Ito and Oyama, 1985). Figure 1(3) shows that if the specialization shown in Table 1(4) were achieved, world outputs of wheat and cloth would increase by 15 (10^8t/year) and 12.5 (10^8m^2/year), respectively. Furthermore, if "proper" trade were carried out by each country, it would be pos-

Table 1. Parameters for the Ricardian model

(1) Output at the primary stage

	Japan	U.S.
Agriculture <Wheat> (10^8t/y)	35	150
Manufacturing <Cloth> (10^8m^2/y)	22.5	40

(2) Allocated labor at the primary stage (10^8ps)

	Japan	U.S.
Agriculuture	0.7	1.5
Manufacturing	0.3	0.5
Total (Endowed)	1.0	2.0

(3) Labor productivity

	Japan	U.S.
Agriculture <Wheat> (t/ps/y)	50	100
Manufacturing <Cloth> (m^2/ps/y)	75	80

(4) Gains in world outputs from specialization

	Wheat (10^8t/y)	Cloth (10^8m^2/y)
World outputs at primary stage	185	62.5
J→Cloth、U.S.→Wheat Specialization	200	75
Gains in world outputs	15	12.5

(1) Output at the primary stage, (2) Allocated labor at the primary stage, (3) Labor productivity, (4) Gains in world outputs from specialization.

sible to realize a state of consumption that would bring about higher standards of living (i.e., welfare). To simplify the discussion, I impose the following two assumptions with respect to the utility function: i) If it is inevitable that the feasible domestic consumption of one or more goods decreases after specialization, even if the domestic consumption of other goods increases, then countries will never accept this type of specialization because they will necessarily experience a drop in the

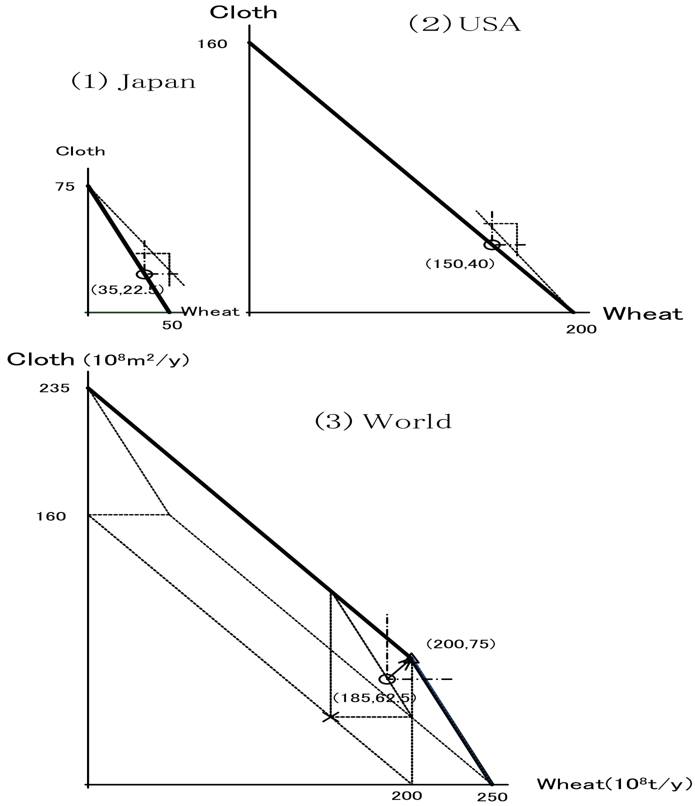


Figure 1. Essential concept of the Ricardian model

standard of living. ii) In the case that does not contradict assumption i), and if it is possible that the feasible domestic consumption of one or more goods increases after specialization, then countries will pursue this type of specialization because they will necessarily experience an increase in the standard of living.

Given these assumptions, the acceptable domain for each country becomes the upper right region (i.e., the region between the two chained lines) of the primary activity point in Figure 1(1) and 1(2). Moreover, because Japanese wheat imports must be equal to U.S. wheat exports and Japanese cloth exports must be equal to U.S. cloth imports, Japan's possible wheat import has an upper limit, and Japan must export more than its lower limit, by an acceptability condition of the U.S. Given these two restrictions, the Japanese domain of feasible consumption is further limited to the rectangular domain surrounded by both the chained lines and dotted lines in Figure 1(1). Likewise, the U.S. domain of feasible consumption is limited to the rectangular domain surrounded by both chained lines and dotted lines in Figure 1(2). It can easily be proven that if the world output of both goods increases as a consequence of specialization, then these domains necessarily exist for each country.

To identify the amount of trade leading each nation to these rectangular domains, lines of terms of trade are used, each of which has the same terms of trade and starts from each activity point after specialization, i.e., (0,75) for Japan and (200,0) for the U.S. In Figure 1(1) and 1(2), a line with 1:1 terms of trade is drawn as an example. This shows the basic implications of the Ricardian model and reveals the reason behind the increase in the standard of living for each country (i.e., each country specializes in the sector where it has a comparative advantage, rather than an absolute advantage, and then exchanges goods "properly" by trade).

2.2. Brief positive analysis of the Ricardian model

"Positive analysis" is an empirical analysis that analyzes the structure and function of an actual economic system. "Normative analysis" is a critical analysis intended to design an ideal economic system, regardless of the actual economies.

Figure 2 shows the weighted correlation between q_r (Japan/U.S. labor productivity) and Δe (the ratio of <Japanese excess exports to U.S.>/<outputs of Japan>) with respect to 24 goods (sectors) listed

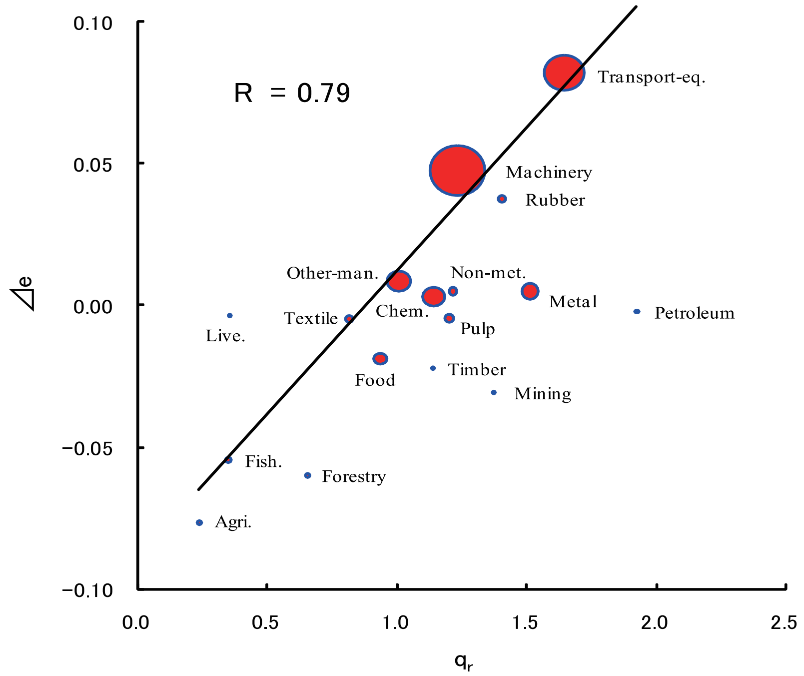


Figure 2. Correlation between q_r and ΔE (Japan/U.S.)

Note) $q_r \equiv q_A/q_B$, where $q_A \equiv X_A/L_A$, $q_B \equiv X_B/L_B$, $\Delta e \equiv \Delta E_{AB}/X_A \equiv (E_{AB} - M_{AB})/X_A$, weight: $w_E = \sqrt{E_A E_B}$.

in Table 4 described below (Krugman and Obstfeld, 2003). Table 2 shows the same correlation coefficients, weighted in the same way, between each pair of countries in the table. Because pairs of countries with significant correlations were limited, one should be careful when applying the Ricardian model for positive analysis among the countries. However, the present study remains valid because its goal is a normative analysis of the impact of the internalization of public benefits from the forestry sector, not a positive analysis of the present pattern of trade. Anyway, Figure 2 shows the applicability of the Ricardian

Table 2. Correlation coefficient between q_r and Δe

A ＼ B	Ind.	Mal.	Phi.	Sin.	Tha.	Chi.	Tai.	Kor.	Japan	USA
Indonesia		-0.12	0.16	-0.37	-0.12	0.43	0.05	0.03	-0.54	-0.26
Malaysia	0.13		0.58	0.29	0.11	-0.09	0.36	0.48	0.46	0.49
Philippines	0.45	0.88		-0.05	-0.06	0.82	0.93	0.65	-0.15	-0.47
Singapore	-0.38	0.01	-0.19		0.29	-0.17	0.77	0.78	0.19	0.84
Thailand	-0.20	0.03	-0.57	0.21		0.26	0.28	0.50	0.37	0.41
China	0.59	0.39	0.53	0.64	0.10		0.12	0.26	0.18	-0.43
Taiwan	-0.10	0.13	0.88	0.49	-0.03	-0.35		0.38	-0.17	-0.45
Korea	0.20	0.45	0.05	0.94	0.08	-0.25	-0.13		-0.37	0.36
Japan	-0.11	-0.21	-0.72	-0.64	0.01	0.21	-0.42	-0.20		0.79
USA	0.04	0.32	-0.30	0.76	0.20	0.12	0.21	0.26	0.66	

model for positive analysis of actual trade between Japan and the U.S., and this fact reinforces the applicability of this model for normative analysis between other countries.

3. Formulation of a linear trade model

3.1. Variables

Terms and variables used in this study are defined as follows. "World market": countries economically affected by the specialization of any country in the group and whose outputs, exports, imports, and so on may change as a result of this specialization. "Countries outside the world market" or "rest of the world": countries unaffected by specialization. $'$: Variables with this superscript may change their value during the process of specialization. Variables without this superscript always retain their primary value. ^{o}: primary or initial value of a variable with a $'$ superscript. K: index of countries within the world market ($K = 1, \ldots, m$). (In the following analysis, instead of K, the subscripts J, A, and C may be used to denote Japan, the U.S., or China, respectively.) i: sector index ($i = 1, \ldots, n$). $\boldsymbol{X}'_K \equiv {}^t(X'_{K1}, \ldots, X'_{Kn})$: vector of outputs in country K. $\boldsymbol{A}_K$: matrix of input coefficients for country

K, which is given by

[1] $$\boldsymbol{A}_K \equiv \begin{pmatrix} a_{K11} & \cdots & a_{K1n} \\ \vdots & \ddots & \vdots \\ a_{Kn1} & \cdots & a_{Knn} \end{pmatrix}$$

$\boldsymbol{F}'_K \equiv {}^t(f'_{K1}, \ldots, f'_{Kn})$: vector of final demand in country K. $\boldsymbol{D}'_K$: total domestic demand for each good in country K ($\boldsymbol{D}'_K = \boldsymbol{A}_K \boldsymbol{X}'_K + \boldsymbol{F}'_K$). $\boldsymbol{E}'_K$: exports of each good from country K. $\boldsymbol{M}'_K$: imports of each good to country K. $\boldsymbol{E}_{KR}$: export of each good from country K to countries outside the world market. ("R"="rest of the world") $\boldsymbol{M}_{KR}$: import of each good from countries outside the world market to country K. $\boldsymbol{G}'_K \equiv (G'_{K1}, \ldots, G'_{Kn})$: vector of gross value added in country K. $\boldsymbol{g}_K \equiv (g_{K1}, \ldots, g_{Kn})$ ($g_{Ki} \equiv G^o_{Ki}/X^o_{Ki}$): vector of gross value added coefficients in country K. $\boldsymbol{L}'_K \equiv (L'_{K1}, \cdots, L'_{Kn})$: vector of employment by sector in country K. $\boldsymbol{l}_K \equiv (l_{K1}, \ldots, l_{Kn})$ ($l_{Ki} \equiv L^o_{Ki}/X^o_{Ki}$): vector of employment coefficients in country K. L^o_K ($\equiv \sum_{i=1}^n \boldsymbol{L}'_{Ki}$): total labor force of country K. ($\boldsymbol{L}^o_K$, the total labor force of each country, is assumed to have been endowed and is therefore fixed.) G'_K ($\equiv \sum_{i=1}^n \boldsymbol{G}'_{Ki}$): GDP of country K. G'_W ($\equiv \sum_{K=1}^m \boldsymbol{G}'_K$): sum of the GDPs of all countries within the world market.

3.2. Restrictions

Restrictions used in this linear trade model are as follows:

1) Restriction on the labor force: The total amount of labor in all sectors in each country cannot exceed the total labor endowment of the economy.

[2] $$\boldsymbol{l}_K \boldsymbol{X}'_K \leq L^o_K \quad (K = 1, \ldots, m)$$

2) Restriction on GDP: The GDP of each country cannot fall below its primary level (the level before specialization) subsequent to specializa-

tion.

[3] $$\boldsymbol{g}_K \boldsymbol{X}'_K \geq G^o_K \quad (K = 1, \ldots, m)$$

3) Restriction on supply and demand: i) The supply of each good must be equal to the demand for that good within the world market.

[4] $$\boldsymbol{S}'_W = \boldsymbol{D}'_W$$

($\boldsymbol{S}'_W$: supply of each good within the world market, $\boldsymbol{D}'_W$: demand for each good within the world market)

[5] $$\boldsymbol{S}'_W = \sum_K \boldsymbol{X}'_K + \sum_K \boldsymbol{M}_{KR}$$

ii) Domestic final demand for each good is linearly dependent on the GDP of the country.

[6] $$\begin{aligned}\boldsymbol{F}'_K &\equiv {}^t(F'_{K1}, \ldots, F'_{Kn}) \\ &= {}^t(\alpha_{K1} G'_K + \beta_{K1}, \ldots, \alpha_{Kn} G'_K + \beta_{Kn}) \\ &= {}^t(\alpha_{K1}, \ldots, \alpha_{Kn})\, G'_K + {}^t(\beta_{K1}, \ldots, \beta_{Kn}) \\ &= {}^t(\alpha_{K1}, \ldots, \alpha_{Kn})\, (g_{K1}, \ldots, g_{Kn})\, {}^t(X'_{K1}, \ldots, X'_{Kn}) \\ &\quad + {}^t(\beta_{K1}, \ldots, \beta_{Kn}) \\ &= \boldsymbol{\alpha}_K \boldsymbol{g}_K \boldsymbol{X}'_K + \boldsymbol{\beta}_K,\end{aligned}$$

where

[7] $$\begin{aligned}&\boldsymbol{\alpha}_K \equiv {}^t(\alpha_{K1}, \ldots, \alpha_{Kn}),\ \boldsymbol{\beta}_K \equiv {}^t(\beta_{K1}, \ldots, \beta_{Kn}) \\ &(\because\ G'_K = g_{K1} X'_{K1} + \cdots + g_{Kn} X'_{Kn})\end{aligned}$$

[8] $$\therefore\ \boldsymbol{D}'_K = \boldsymbol{A}_K \boldsymbol{X}'_K + \boldsymbol{F}'_K = [\boldsymbol{A}_K + \boldsymbol{\alpha}_K \boldsymbol{g}_K]\, \boldsymbol{X}'_K + \boldsymbol{\beta}_K$$

[9] $$\begin{aligned}\therefore\ \boldsymbol{D}'_W &= \sum_K \boldsymbol{D}'_K + \sum_K \boldsymbol{E}_{KR} \\ &= \sum_K [\boldsymbol{A}_K + \boldsymbol{\alpha}_K \boldsymbol{g}_K]\, \boldsymbol{X}'_K + \sum_K \boldsymbol{\beta}_K + \sum_K \boldsymbol{E}_{KR}\end{aligned}$$

iii) From equations [4], [5], [9],

$$\sum_K \boldsymbol{X}'_K + \sum_K \boldsymbol{M}_{KR} = \sum_K [\boldsymbol{A}_K + \boldsymbol{\alpha}_K \boldsymbol{g}_K] \boldsymbol{X}'_K + \sum_K \boldsymbol{\beta}_K + \sum_K \boldsymbol{E}_{KR}. \tag{10}$$

$$\therefore \sum_K [\boldsymbol{I} - \boldsymbol{A}_K - \boldsymbol{\alpha}_K \boldsymbol{g}_K] \boldsymbol{X}'_K = \sum_K [\boldsymbol{E}_K - \boldsymbol{M}_{KR} + \boldsymbol{\beta}_K] \tag{11}$$

($\boldsymbol{\beta}_K = 0$ is assumed. However, tests with random numbers show that almost all realistically meaningful $\boldsymbol{\beta}_K$ values other than $\boldsymbol{\beta}_K = 0$ also lead to feasible solutions of this linear programming problem.)

4) Restriction on the output of each sector: The output of each sector cannot fall below its minimum limit and cannot exceed the maximum potential output of the sector.

$$\begin{aligned} &\gamma_{Kimin} X^o_{Ki} \leq X'_{Ki} \leq \gamma_{Kimax} X^o_{Ki} \\ &(\gamma_{Kimin} < 1,\ \gamma_{Kimax} > 1,\ K = 1, \ldots, m,\ i = 1, \ldots, n) \end{aligned} \tag{12}$$

5) Restriction on non-tradable goods: The absolute value of excess exports of each non-tradable good in each country cannot exceed its absolute value at the primary stage.

$$\begin{aligned} &|\Delta E'_{Ki}| \leq |\Delta E^o_{Ki}| \\ &(\Delta E'_{Ki} \equiv E'_{Ki} - M'_{Ki},\ \Delta E^o_{Ki} \equiv E^o_{Ki} - M^o_{Ki}) \end{aligned} \tag{13}$$

($K = 1, \ldots, m$, $i = i_{NT}$, i_{NT}: sector index for non-tradable goods)

The goods of three sectors, i.e., “20. Electricity etc.,” “21. Construction,” and “24. Public administration,” are treated as non-tradable goods here.

$$\boldsymbol{X}'_K + \boldsymbol{M}'_K = \boldsymbol{D}'_K + \boldsymbol{E}'_K \tag{14}$$

$$\therefore \Delta \boldsymbol{E}'_K = \boldsymbol{X}'_K - \boldsymbol{D}'_K = [\boldsymbol{I} - \boldsymbol{A}_K - \boldsymbol{\alpha}_K \boldsymbol{g}_K] \boldsymbol{X}'_K - \boldsymbol{\beta}_K \tag{15}$$

[16] $$\therefore \ \{\boldsymbol{\beta}_K - |\Delta \boldsymbol{E}_K^o|\}_{i=i_{NT}} \leq \{[\boldsymbol{I} - \boldsymbol{A}_K - \boldsymbol{\alpha}_K \boldsymbol{g}_K]\, \boldsymbol{X}'_K\}_{i=i_{NT}} \leq \{\boldsymbol{\beta}_K + |\Delta \boldsymbol{E}_K^o|\}_{i=i_{NT}}$$

3.3. Objective function

The "objective function" is defined as the total amount of each country's GDP within the world market, and the maximization of this function is planned.

[17] $$\max:\ G'_W \equiv \sum_{K=1}^{m} G'_K = \sum_{K=1}^{m} \boldsymbol{g}_K \boldsymbol{X}'_K$$

3.4. Internalization of the public benefits from the forestry sector in the linear programming model

"True GDP" is defined as the sum of the GDP and public benefit, in monetary terms, provided by the forestry sector in the country, and this index denotes the true welfare of the nation (Ejiri, 1996, 1999a). This study recognizes that many forestry operations, such as thinning (not clear cutting), may result in a simultaneous impact - producing timber and benefiting the public, for example (Ohta, I., 2005, Ohta, T., 2005, Yoshimoto *et al.*, 2005). The forestry sector's support of local communities and the forests they depend on is also considered a public benefit. Therefore, public benefits, in monetary terms, provided by the forestry sector are collectively handled as follows.

No matter whether "zoning" is done or not, public benefits (in monetary terms) provided by the forestry sector in the country can be attributed to a) public benefits that are independent of output, b) public benefits that are considered part of the increasing function of relevant forestry output, or c) public benefits that are considered part of the decreasing function of relevant forestry output. That is to say,

$$[18] \qquad \begin{aligned} &\varphi'_K = c_K + \varphi_{KA}\left(X'_{KFA}\right) + \varphi_{KB}\left(X'_{KFB}\right), \\ &\left(X'_{KF} = X'_{KFA} + X'_{KFB}\right) \end{aligned}$$

where φ'_K is the amount of public benefit, in monetary terms, provided by the forestry sector in country K (unit: 10^{10} \$/year), c_K is constant that is independent of the values of X'_{KFA} or X'_{KFB} (unit: 10^{10} \$/year), $\varphi_{KA}\left(X'_{KFA}\right)$ is increasing function of X'_{KFA}, $\varphi_{KB}\left(X'_{KFB}\right)$ is decreasing function of X'_{KFB}, X'_{KF} is output of the forestry sector or primary industry in country K, ($_F$: the sector number of forestry or primary industry. Unit: 10^{10} \$/year), X'_{KFA}, X'_{KFB} are the portion of X'_{KF} that can be categorized into a variable of φ_{KA} and φ_{KB}, respectively (unit: 10^{10} \$/year).

This study adopts the following linear approximation:

$$[19] \qquad \begin{aligned} &\varphi_{KA}\left(X'_{KFA}\right) = c_{KA} + d_{KA}X'_{KFA}, \\ &\varphi_{KB}\left(X'_{KFB}\right) = c_{KB} - d_{KB}X'_{KFB} \end{aligned}$$

where c_{KA}, d_{KA}, c_{KB}, d_{KB} are constants(> 0). Therefore equation [18] can be transformed as follows.

$$[20] \qquad \begin{aligned} \varphi'_K - c_K - c_{KA} - c_{KB} &= d_{KA}X'_{KFA} - d_{KB}X'_{KFB} \\ &= \left(d_{KA}\frac{X'_{KFA}}{X'_{KF}} - d_{KB}\frac{X'_{KFB}}{X'_{KF}}\right)X'_{KF} \end{aligned}$$

This study assumes the following relations:

$$[21] \qquad \frac{X'_{KFA}}{X^o_{KFA}} = \frac{X'_{KFB}}{X^o_{KFB}} = \frac{X'_{KF}}{X^o_{KF}}$$

where X^o_{KF}, X^o_{KFA}, X^o_{KFB} are the present value of X'_{KF}, X'_{KFA} and X'_{KFB}, respectively. Under this assumption, equation [20] can be transformed as follows.

$$[22] \qquad \varphi'_K - c_K - c_{KA} - c_{KB} = \left(d_{KA}\frac{X^o_{KFA}}{X^o_{KF}} - d_{KB}\frac{X^o_{KFB}}{X^o_{KF}}\right)X'_{KF}$$

If $\varphi'_K - c_K - c_{KA} - c_{KB}$ is redefined as φ'_K, it can be rewritten as follows.

[23] $$\varphi'_K = \frac{\varphi^o_K}{X^o_{KF}} X'_{KF} \quad (K = 1, \ldots, m)$$

where, $\varphi^o_K (\equiv d_{KA} X^o_{KFA} - d_{KB} X^o_{KFB})$ (parameter) is the level of public benefits, except what is independent of the values of X'_{KFA} and X'_{KFB}, in monetary terms, provided by the forestry sector in country K, assuming that the forestry sector maintains its present output level (i.e., before specialization). This condition only fixes the output level, not the type of forestry operations. Therefore, this value may change depending on the nature of future forestry operations. There is also the possibility of $\varphi^o_K \leq 0$ in some countries.

Using equation [23], the objective function [17] is transformed into the following equation [24]:

[24] $$G'_{\varphi W} \equiv \sum_{K=1}^{m} G'_{\varphi K}$$

[25] $$\begin{aligned} r &= \sum_{K=1}^{m} (G'_K + \varphi'_K) \\ &= \sum_{K=1}^{m} \{ g_{K1} X'_{K1} + \cdots + (g_{KF} + \varphi^o_K / X^o_{KF}) X'_{KF} \\ &\qquad\qquad + \cdots + g_{Kn} X'_{Kn} \} \end{aligned}$$

where $G'_{\varphi W}$ is the sum of the true GDP of each country within the world market and $G'_{\varphi K}$ is the true GDP of country K $(G'_{\varphi K} \equiv G'_K + \varphi'_K)$. The optimal solution (i.e., the set of optimal outputs of each sector) that maximizes the sum of true GDP in the world is investigated using the simplex method.

3.5. Key concepts of the model

Table 3 and Figure 3 show the key concepts of the main body of this model (i.e., equations [2]–[12], [17]) using a hypothetical input-output table (Morishima, 1956, Niida, 1978). Table 3(1) indicates the input-output data of each country at the primary stage. Outputs and allocated labor force in this table are the same as in the previous schematic model (Ejiri, 2008). Under restrictions [2], [3], [11], [12] without equation [16], the objective function [17] is attempted to maximize. Table 3(2) denotes the optimal outputs of each country, i.e., the optimal solutions of this linear programming problem and other derived values. This optimal solution is denoted by the activity point T. The process of deriving this optimal point can be explained as follows:

Equation [2] defines the production possibility frontiers of each country as lines AB and CD in Figure 3. (For the purpose of simplicity, idle labor forces are not considered.) Then, inequality [12] restricts each of the production possibility frontiers within the ranges of GH and US. Inequality [3] further restricts each of the production possibility frontiers within the limited ranges of GE and PS. Each line consists of the set of activity points that produce constant GDP, meaning that $G^o_{DPJ} = 10.0$, $G'_{DPJ} = 11.0$, $G^o_{DPA} = 44.0$, and $G'_{DPA} = 46.8$, respectively, as are also drawn in Figure 3. Given these restrictions, the production possibility frontier in the world is specified as parallelogram PQRS.

Figure 3 also shows that the domain of the world's "final demand possibility frontier," not the production possibility frontier, consists of the set of possible world final demand (F_{W1}, F_{W2}) for each good, as parallelogram P'Q'R'S' corresponding to parallelogram PQRS. This domain is identified as follows. A final demand possibility frontier for each country is first identified by the equation $\boldsymbol{F} = [\boldsymbol{I} - \boldsymbol{A}]\boldsymbol{X}$ ($\boldsymbol{F}$: final demand of each country in a broad sense, including exports and imports

Table 3. Input-output table at each activity point in Figure 3

(A) Japan

(1) Before specialization (Point P)

	x_{ij}^o		Σ	F_D^o	⊿E^o	X^o
x_{ij}^o	6	2	8	7	0	15
	3	4	7	3	0	10
G^o	6	4	10	*	*	*
X^o	15	10	25	*	*	*
L^o	0.75	0.25	1.00	*	*	*

(10^{11}\$/yr, 10^8ps)

↓

(2) After specialization (Point S)

	x'_{ij}		Σ	F'_D	⊿E'	X'
x'_{ij}	5.0	3.0	8.0	7.7	-3.2	12.5
	2.5	6.0	8.5	3.3	3.2	15.0
G'	5.0	6.0	11.0	*	*	*
X'	12.5	15.0	27.5	*	*	*
L'	0.625	0.375	1.00	*	*	*

(γ_{imin}=0.5, γ_{imax}=1.5)

(3) Input Coefficients etc.

	a_{ij}		**α**	**β**
a_{ij}	0.4	0.2	0.7	0
	0.2	0.4	0.3	0
g	0.4	0.4	*	*
l	0.05	0.025	*	*

(G_{DPJ}=0.4X_{J1}+0.4X_{J2})

(B) USA

(1) Before specialization (Point E)

	x_{ij}^o		Σ	F_D^o	⊿E^o	X^o
x_{ij}^o	18	4	22	38	0	60
	6	8	14	6	0	20
G^o	36	8	44	*	*	*
X^o	60	20	80	*	*	*
L^o	1.20	0.80	2.00	*	*	*

(10^{11}\$/yr, 10^8ps)

↓

(2) After specialization (Point F)

	x'_{ij}		Σ	F'_D	⊿E'	X'
x'_{ij}	20.1	3.3	23.4	40.4	3.2	67.0
	6.7	6.6	13.3	6.4	-3.2	16.5
G'	40.2	6.6	46.8	*	*	*
X'	67.0	16.5	83.5	*	*	*
L'	1.34	0.66	2.00	*	*	*

(γ_{imin}=0.5, γ_{imax}=1.5)

(3) Input Coefficients etc.

	a_{ij}		**α**	**β**
a_{ij}	0.3	0.2	0.86	0
	0.1	0.4	0.14	0
g	0.6	0.4	*	*
l	0.02	0.04	*	*

(G_{DPA}=0.6X_{A1}+0.4X_{A2})

(1) Before specialization, (2) After specialization.

$[\equiv \boldsymbol{F}_D + \Delta\boldsymbol{E};\ \Delta\boldsymbol{E} \equiv \boldsymbol{E} - \boldsymbol{M}]$; $\boldsymbol{X}$: output of the country). Then, the world's final demand possibility frontier is identified as P'Q'R'S' using the two frontiers of each country.

Because the equation $G_{DPK} = \sum_{i=1}^{n} F_{Ki}$ holds for each country, the next equation also holds:

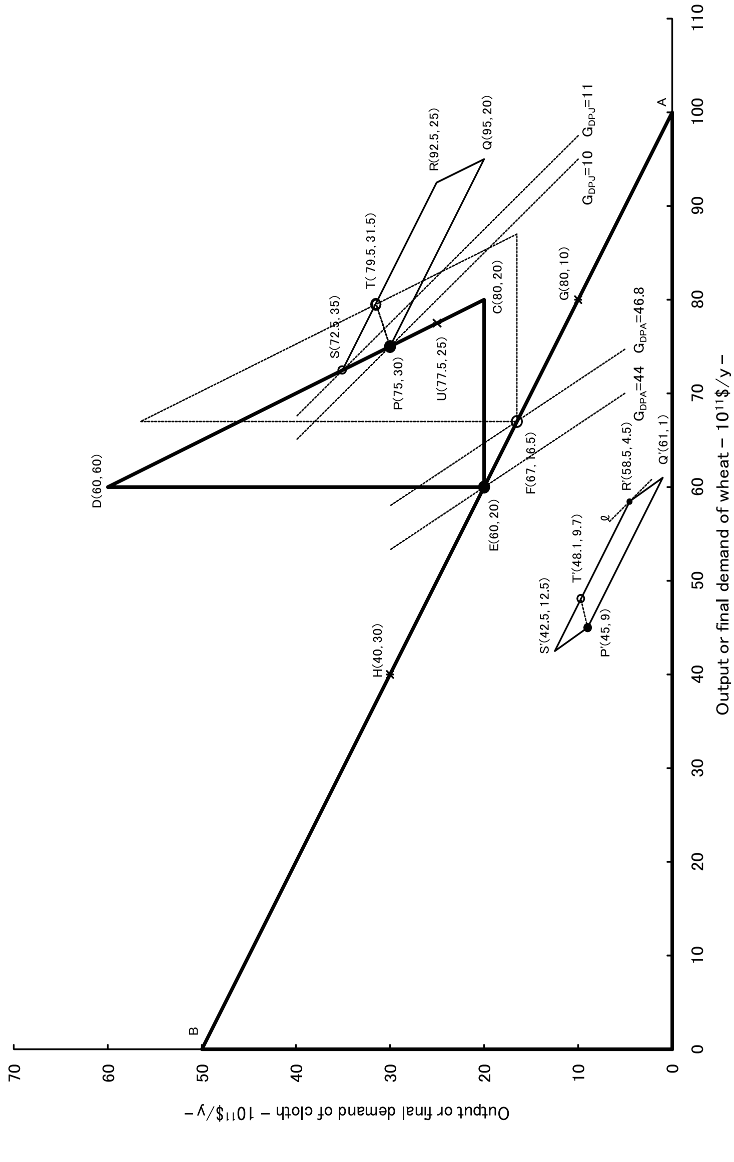


Figure 3. Combination of Recardian model and input-output table

[26]
$$G_{DPW} \equiv \sum_{K=1}^{m} G_{DPK} = \sum_{K=1}^{m} \sum_{i=1}^{n} F_{Ki} = \sum_{i=1}^{n} \sum_{K=1}^{m} F_{Ki} = \sum_{i=1}^{n} F_{Wi}$$

In this case, $n = 2$, and therefore the set (F_{W1}, F_{W2}) that brings out equal G_{DPW} forms lines with slopes of -45 degrees, e.g., line l. The point (F_{W1}, F_{W2}) that maximizes the G_{DPW} within the range P′Q′R′S′ is identified as point R′. R′ is a point corresponding to the output point R. Because of the restrictions from equations [11], the optimal solution that maximizes G_{DPW} settles on point T′. The point corresponding to T′, identified by the equation $\boldsymbol{X} = [\boldsymbol{I} - \boldsymbol{A}]^{-1}\boldsymbol{F}$, is point T. After all, the maximization of equation [17] under the additional restriction of equations [11] is attained at an activity point T within the parallelogram domain PQRS. Table 3 and Figure 3 also show that the GDPs of each country grow from 10.0 to 11.0 (10^{11} \$/y) for Japan and from 44.0 to 46.8 (10^{11} \$/y) for the U.S. as a result of this specialization. This information describes the key concept of the main body of this model, which is essentially a combination of the Ricardian model and the input-output table.

4. Data

The "Asian International Input-Output Table 2000" (Institute of Developing Economies, Japan External Trade Organization, 2006) provided the basic data. Table 4 shows output and employment data for each sector in Japan, the U.S., and China. Table 5 indicates how each sector may be aggregated for the purpose of investigating the effects of aggregation.

5. Results

In what follows, 10^{10} \$ is the monetary unit and 10^4 workers is the labor force unit. Furthermore, the degree X'_{Ki}/X^o_{Ki} to which the output of each sector increases subsequent to specialization is referred to as the "rate of output increase." Additionally, I denote the rate of output increase for the forestry sector (or primary industry output in cases in which the forestry sector is aggregated) in country K by f_K. This is explicitly defined as $f_K \equiv X'_{KF}/X^o_{KF}$.

Table 6 shows the impact of public benefits from the forestry sector on patterns of specialization. Table 6(a) shows that when public benefits from the forestry sector are not taken into account, it is desirable for Japan to reduce its level of forestry output (and level of "Agriculture & Fishery" output as well) and increase its level of transport equipment output. In contrast, it is desirable for the U.S. to increase the former and reduce the latter. Table 6(b) shows that when public benefits from the forestry sector are considered as $\varphi^o_J = 1.0$, $\varphi^o_A = 1.0$, $\varphi^o_C = 0$, (10^{10} \$/year), the specialization patterns of Japanese and U.S. forestry change.

Table 7 indicates the way in which f_K, or the rate of output increase of the forestry sector in each country, changes for each assumed value of φ^o_J, φ^o_A, and under $\varphi^o_C \equiv 0$ after ideal specialization, i.e., as a result of the maximization of the objective function [24], [25]. The values of q_{GK} that correspond to each φ^o_K are also listed in Table 7. q_{GK} is defined as the value of the rate of gross value-added increase in the forestry sectors. That is, q_{GK} is calculated as

$$[27] \qquad q_{GK} \equiv \frac{g_{KF} + \varphi^o_K / X^o_{KF}}{g_{KF}} = 1 + \frac{\varphi^o_K}{g_{KF} X^o_{KF}} = 1 + \frac{\varphi^o_K}{G^o_{KF}}$$

Table 8 shows the same changes for each assumed value of φ^o_J, φ^o_C, under $\varphi^o_A \equiv 0$.

Table 4. Output, gross value added etc. and employment in each sector -2000 yr-

(10^{10}\$/year, 10^{6}persons)

Japan

Sectors	A_{XJ}	F_{DJ}	E_{JC}	E_{JA}	E_{JR}	M_{JC}	M_{JA}	M_{JR}	X_J	G_J	L_J
1 Paddy	2.25	0.02	0.00	0.00	0.00	0.00	0.00	0.01	2.26	1.44	2.46
2 Other agricultural products	2.93	2.78	0.00	0.00	0.01	0.06	0.37	0.52	4.77	3.09	1.89
3 Livestock and poultry	2.31	0.36	0.00	0.00	0.00	0.01	0.01	0.01	2.64	0.64	0.71
4 Forestry	0.77	0.80	0.00	0.00	0.00	0.02	0.08	0.15	1.32	0.91	0.11
5 Fishery	1.68	0.42	0.00	0.01	0.04	0.04	0.11	0.21	1.79	1.02	0.31
6 Crude petroleum and natural gas	5.79	-0.02	0.00	0.00	0.00	0.10	0.04	5.56	0.08	0.05	0.00
7 Other mining	2.49	0.00	0.00	0.00	0.01	0.06	0.04	1.21	1.20	0.50	0.05
8 Food, beverage and tobacco	12.70	26.50	0.01	0.04	0.14	0.45	0.72	2.20	36.02	14.28	1.48
9 Textile, leather, and the products thereof	4.01	5.55	0.24	0.05	0.36	1.44	0.08	1.34	7.35	2.76	0.78
10 Timber and wooden products	5.22	0.67	0.00	0.00	0.02	0.11	0.11	0.79	4.91	1.88	0.38
11 Pulp, paper and printing	17.76	1.66	0.04	0.06	0.20	0.02	0.15	0.30	19.25	7.95	0.97
12 Chemical products	20.62	2.55	0.44	0.54	2.34	0.12	0.47	1.58	24.32	8.01	0.53
13 Petroleum and petro products	9.47	3.85	0.02	0.01	0.25	0.04	0.04	1.47	12.05	5.69	0.04
14 Rubber products	2.21	0.08	0.02	0.12	0.33	0.01	0.02	0.10	2.63	1.03	0.12
15 Non-metallic mineral products	7.29	0.31	0.07	0.09	0.31	0.09	0.05	0.16	7.77	3.38	0.41
16 Metal products	32.33	0.69	0.43	0.39	1.91	0.25	0.22	1.60	33.67	11.73	1.40
17 Machinery	35.89	33.58	1.50	5.74	13.88	0.73	1.81	5.21	82.83	30.34	3.53
18 Transport equipment	23.33	13.36	0.13	4.36	6.33	0.06	0.60	0.93	45.93	12.54	1.68
19 Other manufacturing products	12.43	5.49	0.14	0.65	1.56	0.29	0.50	1.51	17.97	6.56	1.10
20 Electricity, gas, and water supply	14.98	6.91	0.00	0.00	0.03	0.00	0.00	0.00	21.92	11.78	0.36
21 Construction	8.33	63.40	0.00	0.00	0.00	0.00	0.00	0.00	71.74	32.84	6.58
22 Trade and transport	55.47	67.83	0.41	1.42	6.44	0.59	1.15	3.92	125.90	82.17	17.23
23 Services	119.23	190.31	0.00	0.00	1.98	0.00	0.03	5.20	306.30	203.27	24.15
24 Public administration	0.66	32.96	0.00	0.00	0.00	0.00	0.00	0.00	33.61	24.21	2.01
25 Total of all sectors	400.16	460.07	3.45	13.49	36.13	4.49	6.61	33.97	868.23	468.06	68.29

USA

Sectors	A_{XA}	F_{DA}	E_{AC}	E_{AJ}	E_{AR}	M_{AC}	M_{AJ}	M_{AR}	X_A	G_A	L_A
1 Paddy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 Other agricultural products	8.58	2.75	0.08	0.37	0.54	0.01	0.00	1.19	11.92	5.67	1.12
3 Livestock and poultry	10.43	0.43	0.00	0.01	0.04	0.00	0.00	0.28	10.73	1.64	1.03
4 Forestry	2.61	0.15	0.00	0.08	0.03	0.00	0.00	0.09	2.83	1.39	0.15
5 Fishery	0.59	0.20	0.00	0.11	0.05	0.03	0.01	0.60	0.37	0.21	0.02
6 Crude petroleum and natural gas	23.86	1.94	0.00	0.04	0.01	0.01	0.00	9.93	16.01	9.34	0.43
7 Other mining	4.57	0.41	0.01	0.04	0.12	0.01	0.00	0.31	4.97	2.59	0.26
8 Food, beverage and tobacco	20.31	36.04	0.08	0.72	0.73	0.07	0.04	3.48	55.63	19.37	2.14
9 Textile, leather, and the products thereof	7.49	15.06	0.02	0.08	0.25	0.93	0.05	8.66	14.70	5.19	1.27
10 Timber and wooden products	10.85	5.13	0.01	0.11	0.16	0.26	0.00	2.43	13.97	4.98	1.23
11 Pulp, paper and printing	31.44	5.95	0.08	0.15	0.55	0.05	0.06	2.12	37.05	16.40	2.23
12 Chemical products	32.53	14.81	0.24	0.47	2.91	0.18	0.54	9.37	44.26	16.13	1.10
13 Petroleum and petro products	17.49	8.27	0.01	0.04	0.26	0.02	0.01	2.38	24.60	2.37	0.16
14 Rubber products	2.94	0.96	0.00	0.02	0.07	0.05	0.12	0.60	3.47	1.43	0.23
15 Non-metallic mineral products	9.77	0.67	0.02	0.05	0.15	0.19	0.09	1.08	9.67	4.65	0.62
16 Metal products	44.46	5.08	0.10	0.22	0.80	0.57	0.39	5.91	46.00	17.32	2.90
17 Machinery	52.10	49.35	0.75	1.81	9.30	2.36	5.74	23.60	91.82	39.37	4.82
18 Transport equipment	31.40	56.28	0.15	0.60	3.74	0.25	4.36	16.07	78.78	25.48	4.74
19 Other manufacturing products	21.47	15.58	0.12	0.50	2.12	1.14	0.65	6.70	34.01	15.26	2.09
20 Electricity, gas, and water supply	24.53	17.26	0.00	0.00	0.00	0.00	0.00	0.29	41.61	18.44	1.02
21 Construction	11.20	79.90	0.00	0.00	0.00	0.00	0.00	0.00	91.12	39.01	9.47
22 Trade and transport	98.54	135.86	0.26	1.15	4.19	1.10	1.42	3.83	244.87	149.30	28.42
23 Services	348.30	458.28	0.00	0.03	0.10	0.01	0.00	15.74	806.71	515.23	74.37
24 Public administration	0.00	109.35	0.00	0.00	0.00	0.00	0.00	0.00	109.35	68.21	4.31
25 Total of all sectors	815.47	1019.71	1.93	6.61	26.14	7.25	13.49	114.66	1794.46	978.99	144.13

China

Sectors	A_{XC}	F_{DC}	E_{CJ}	E_{CA}	E_{CR}	M_{CJ}	M_{CA}	M_{CR}	X_C	G_C	L_C
1 Paddy	3.09	1.98	0.00	0.00	0.00	0.00	0.00	0.00	5.08	3.14	129.10
2 Other agricultural products	7.98	4.20	0.06	0.01	0.32	0.00	0.08	0.28	12.22	7.74	310.58
3 Livestock and poultry	3.61	6.35	0.01	0.00	0.02	0.00	0.00	0.12	9.87	4.75	12.69
4 Forestry	0.83	0.40	0.02	0.00	0.01	0.00	0.00	0.20	1.07	0.76	1.68
5 Fishery	1.28	1.60	0.04	0.03	0.02	0.00	0.00	0.00	2.96	1.74	3.59
6 Crude petroleum and natural gas	6.02	0.58	0.10	0.01	0.06	0.00	0.00	1.48	5.29	3.62	0.53
7 Other mining	4.43	0.12	0.06	0.01	0.17	0.00	0.01	0.44	4.33	2.00	6.61
8 Food, beverage and tobacco	6.42	11.04	0.45	0.07	0.55	0.01	0.08	0.39	18.04	5.86	8.45
9 Textile, leather, and the products thereof	11.70	4.45	1.44	0.93	3.76	0.24	0.02	1.13	20.89	5.89	19.74
10 Timber and wooden products	1.37	0.20	0.11	0.26	0.20	0.00	0.01	0.18	1.95	0.53	5.31
11 Pulp, paper and printing	4.71	0.38	0.02	0.05	0.13	0.04	0.08	0.46	4.70	1.51	3.40
12 Chemical products	18.09	2.14	0.12	0.18	1.04	0.44	0.24	2.01	18.88	5.03	5.51
13 Petroleum and petro products	10.15	-0.40	0.04	0.02	0.32	0.02	0.01	0.51	9.60	2.44	0.63
14 Rubber products	1.71	0.39	0.01	0.05	0.17	0.02	0.00	0.07	2.24	0.54	0.88
15 Non-metallic mineral products	6.67	0.63	0.09	0.19	0.31	0.07	0.02	0.12	7.68	2.35	7.25
16 Metal products	19.75	-0.15	0.25	0.57	1.38	0.43	0.10	1.61	19.65	4.54	7.79
17 Machinery	25.23	12.36	0.73	2.36	4.95	1.50	0.75	5.60	37.79	9.79	16.02
18 Transport equipment	6.60	4.87	0.06	0.25	0.58	0.13	0.15	0.34	11.73	3.04	5.47
19 Other manufacturing products	5.95	0.13	0.29	1.14	1.81	0.14	0.12	0.51	8.56	2.31	8.74
20 Electricity, gas, and water supply	10.55	1.00	0.00	0.00	0.06	0.00	0.00	0.01	11.60	4.75	4.47
21 Construction	1.65	25.14	0.00	0.00	0.03	0.00	0.00	0.05	26.76	7.38	19.14
22 Trade and transport	18.39	4.07	0.59	1.10	1.74	0.41	0.26	0.66	24.56	11.96	55.07
23 Services	20.36	18.44	0.00	0.01	0.66	0.00	0.00	0.56	38.91	19.80	62.09
24 Public administration	0.00	6.74	0.00	0.00	0.03	0.00	0.00	0.02	6.75	3.10	16.77
25 Total of all sectors	196.54	106.67	4.49	7.25	18.31	3.45	1.93	16.76	311.11	114.58	711.50

A_{XJ}: Intermediate demand (Japan)
F_{DJ}: Final domestic demand (")
E_{JC}: Export to China (")
E_{JA}: Export to the USA (")
E_{JR}: Export to other countries (")
M_{JC}: Import from China (")
M_{JA}: Import from the USA (")
M_{JR}: Import from other countries (")
X_J: Output (")
G_J: Gross value added (")
L_J: Employment (")
etc.

Table 5. Aggregation of sectors

24 sectors		15 sectors		14 sectors		3 sectors	
1	Paddy	1	Agri etc.	1	Primary industries	1	Primary industries
2	Other agricultural products	1	Agri etc.	1	Primary industries	1	Primary industries
3	Livestock and poultry	1	Agri etc.	1	Primary industries	1	Primary industries
4	Forestry	2	Forestry	1	Primary industries	1	Primary industries
5	Fishery	1	Agri etc.	1	Primary industries	1	Primary industries
6	Crude petroleum and natural gas	3	Mining	2	Mining	2	Secondary industries
7	Other mining	3	Mining	2	Mining	2	Secondary industries
8	Food, beverage and tobacco	4	Food, beverage and tobacco	3	Food, beverage and tobacco	2	Secondary industries
9	Textile, leather, and the products thereof	11	Other manufacturing products	10	Other manufacturing products	2	Secondary industries
10	Timber and wooden products	11	Other manufacturing products	10	Other manufacturing products	2	Secondary industries
11	Pulp, paper and printing	11	Other manufacturing products	10	Other manufacturing products	2	Secondary industries
12	Chemical products	5	Chemical products	4	Chemical products	2	Secondary industries
13	Petroleum and petro products	6	Petroleum and petro products	5	Petroleum and petro products	2	Secondary industries
14	Rubber products	7	Rubber products	6	Rubber products	2	Secondary industries
15	Non-metallic mineral products	11	Other manufacturing products	10	Other manufacturing products	2	Secondary industries
16	Metal products	8	Metal products	7	Metal products	2	Secondary industries
17	Machinery	9	Machinery	8	Machinery	2	Secondary industries
18	Transport equipment	10	Transport equipment	9	Transport equipment	2	Secondary industries
19	Other manufacturing products	11	Other manufacturing products	10	Other manufacturing products	2	Secondary industries
20	Electricity, gas, and water supply	12	Electricity, gas, and water supply	11	Electricity, gas, and water supply	3	Tertiary industries
21	Construction	13	Construction	12	Construction	3	Tertiary industries
22	Trade and transport	14	Services	13	Services	3	Tertiary industries
23	Services	14	Services	13	Services	3	Tertiary industries
24	Public administration	15	Public administration	14	Public administration	3	Tertiary industries

Table 6. Impact of public benefits from the forestry sector on patterns of international specialization-15 Sectors, $\gamma_{min} = 0.5$, $\gamma_{max} = 1.5$-

- 15 Sectors, $\gamma_{\mathbf{min}} = 0.5$, $\gamma_{\mathbf{max}} = 1.5$ -

(a) $\varphi_J{}^o = 0$, $\varphi_A{}^o = 0$, $\varphi_C{}^o = 0$

	Sectors	X_{Jo}	X_{Ao}	X_{Co}	x_{Wo}	X_J	X_A	X_C	X_W	X_J/X_{Jo}	X_A/X_{Ao}	X_C/X_{Co}	X_W/X_{Wo}	⊿G_J	⊿G_A	⊿G_C	⊿G_W	⊿L_J	⊿L_A	⊿L_C
1	Agri. & Fishery	11.5	23.0	30.1	64.6	5.7	34.5	26.9	67.2	0.50	1.50	0.89	1.04	-3.09	3.76	-1.87	-1.20	-2.69	1.09	-49.03
2	Forestry	1.3	2.8	1.1	5.2	1.0	4.2	0.5	5.7	0.74	1.50	0.50	1.10	-0.24	0.70	-0.38	0.07	-0.03	0.08	-0.84
3	Mining	1.3	21.0	9.6	31.9	0.6	28.5	4.8	34.0	0.50	1.36	0.50	1.07	-0.27	4.29	-2.81	1.21	-0.02	0.25	-3.57
4	Food, beverage and tobacco	36.0	55.6	18.0	109.7	21.1	83.4	9.0	113.6	0.59	1.50	0.50	1.04	-5.92	9.68	-2.93	0.83	-0.61	1.07	-4.22
5	Chemical products	24.3	44.3	18.9	87.5	12.7	66.4	9.4	88.6	0.52	1.50	0.50	1.01	-3.82	8.07	-2.52	1.73	-0.25	0.55	-2.75
6	Petroleum and petro products	12.0	24.6	9.6	46.2	18.1	25.7	4.8	48.5	1.50	1.04	0.50	1.05	2.84	0.10	-1.22	1.73	0.02	0.01	-0.32
7	Rubber products	2.6	3.5	2.2	8.3	3.9	1.7	3.1	8.8	1.50	0.50	1.39	1.05	0.51	-0.71	0.21	0.01	0.06	-0.12	0.34
8	Metal products	33.7	46.0	19.7	99.3	50.4	23.0	29.5	102.9	1.50	0.50	1.50	1.04	5.83	-8.66	2.27	-0.56	0.70	-1.45	3.89
9	Machinery	82.8	91.8	37.8	212.4	56.0	137.7	20.5	214.3	0.68	1.50	0.54	1.01	-9.83	19.68	-4.47	5.39	-1.14	2.41	-7.32
10	Transport equipment	45.9	78.8	11.7	136.4	68.9	57.9	17.6	144.4	1.50	0.74	1.50	1.06	6.27	-6.75	1.52	1.05	0.84	-1.26	2.74
11	Other manufacturing products	57.2	109.4	43.8	210.4	28.6	139.2	44.6	212.5	0.50	1.27	1.02	1.01	-11.26	12.67	0.23	1.64	-1.82	2.03	0.82
12	Electricity, gas, and water supply	21.9	41.6	11.6	75.1	21.8	43.1	11.5	76.4	0.99	1.03	0.99	1.02	-0.06	0.65	-0.04	0.54	0.00	0.04	-0.04
13	Construction	71.7	91.1	26.8	189.6	74.1	92.2	28.3	194.7	1.03	1.01	1.06	1.03	1.09	0.47	0.43	1.99	0.22	0.11	1.13
14	Services	432.2	1051.6	63.5	1547.3	480.9	1001.8	95.2	1577.9	1.11	0.95	1.50	1.02	32.14	-31.44	15.88	16.58	4.66	-4.86	58.58
15	Public administration	33.6	109.3	6.8	149.7	34.8	110.9	7.0	152.6	1.03	1.01	1.04	1.02	0.82	0.94	0.11	1.88	0.07	0.06	0.60
16	Total of all sectors	868.2	1794.5	311.1	2973.8	878.7	1850.4	312.8	3041.9	1.01	1.03	1.01	1.02	15.02	13.46	4.42	32.90	0.00	0.00	0.00

X_{Jo} : Output before specialization (Japan), X_J : Output after specialization (Japan)

⊿$G_J \equiv G_J - G_{JO}$ (G_{JO} : Gross value added before specialization, G_J : 〃 after specialization; Japan)

⊿$L_J \equiv L_J - L_{JO}$ (L_{JO} : Enployment before specialization, L_J : 〃 after specialization; Japan) etc.

(b) $\varphi_J{}^o = 1.0$, $\varphi_A{}^o = 1.0$, $\varphi_C{}^o = 0$

	Sectors	X_{Jo}	X_{Ao}	X_{Co}	x_{Wo}	X_J	X_A	X_C	X_W	X_J/X_{Jo}	X_A/X_{Ao}	X_C/X_{Co}	X_W/X_{Wo}	⊿G_J	⊿G_A	⊿G_C	⊿G_W	⊿L_J	⊿L_A	⊿L_C
1	Agri. & Fishery	11.5	23.0	30.1	64.6	5.7	34.5	26.9	67.2	0.50	1.50	0.89	1.04	-3.09	3.76	-1.87	-1.20	-2.69	1.09	-49.00
2	Forestry	1.3	2.8	1.1	5.2	2.0	3.1	0.5	5.6	1.50	1.11	0.50	1.08	0.46	0.15	-0.38	0.22	0.05	0.02	-0.84
3	Mining	1.3	21.0	9.6	31.9	0.6	28.5	4.8	34.0	0.50	1.36	0.50	1.07	-0.27	4.28	-2.81	1.20	-0.02	0.25	-3.57
4	Food, beverage and tobacco	36.0	55.6	18.0	109.7	21.1	83.4	9.0	113.5	0.59	1.50	0.50	1.04	-5.92	9.68	-2.93	0.83	-0.61	1.07	-4.22
5	Chemical products	24.3	44.3	18.9	87.5	12.6	66.4	9.4	88.5	0.52	1.50	0.50	1.01	-3.85	8.07	-2.52	1.70	-0.25	0.55	-2.75
6	Petroleum and petro products	12.0	24.6	9.6	46.2	18.1	25.7	4.8	48.5	1.50	1.04	0.50	1.05	2.84	0.10	-1.22	1.73	0.02	0.01	-0.32
7	Rubber products	2.6	3.5	2.2	8.3	3.7	1.7	3.4	8.8	1.40	0.50	1.50	1.05	0.42	-0.71	0.27	-0.02	0.05	-0.12	0.44
8	Metal products	33.7	46.0	19.7	99.3	50.2	23.0	29.5	102.7	1.49	0.50	1.50	1.03	5.76	-8.66	2.27	-0.63	0.69	-1.45	3.89
9	Machinery	82.8	91.8	37.8	212.4	57.1	137.7	19.3	214.2	0.69	1.50	0.51	1.01	-9.42	19.68	-4.78	5.48	-1.10	2.41	-7.82
10	Transport equipment	45.9	78.8	11.7	136.4	68.9	57.9	17.6	144.4	1.50	0.73	1.50	1.06	6.27	-6.76	1.52	1.04	0.84	-1.26	2.74
11	Other manufacturing products	57.2	109.4	43.8	210.4	28.6	138.9	45.0	212.5	0.50	1.27	1.03	1.01	-11.26	12.52	0.35	1.61	-1.82	2.00	1.23
12	Electricity, gas, and water supply	21.9	41.6	11.6	75.1	21.8	43.1	11.5	76.3	0.99	1.03	0.99	1.02	-0.06	0.64	-0.04	0.53	0.00	0.04	-0.04
13	Construction	71.7	91.1	26.8	189.6	74.1	92.2	28.3	194.6	1.03	1.01	1.06	1.03	1.10	0.46	0.43	1.99	0.22	0.11	1.10
14	Services	432.2	1051.6	63.5	1547.3	479.7	1002.7	95.2	1577.7	1.11	0.95	1.50	1.02	31.38	-30.86	15.88	16.40	4.55	-4.77	58.58
15	Public administration	33.6	109.3	6.8	149.7	34.8	110.8	7.0	152.6	1.03	1.01	1.03	1.02	0.83	0.93	0.11	1.87	0.07	0.06	0.58
16	Total of all sectors	868.2	1794.5	311.1	2973.8	879.1	1849.8	312.3	3041.1	1.01	1.03	1.00	1.02	15.17	13.30	4.28	32.75	0.00	0.00	0.00

In what follows, “primary domain” is defined in $\varphi_J^o - \varphi_A^o - \varphi_C^o$ space as the domain in which the same increasing or decreasing state of output as the original state (i.e., the state of $\varphi_J^o = \varphi_A^o = \varphi_C^o = 0$) is maintained. In other words, because $f_J < 1.0$, $f_A > 1.0$, or $f_C < 1.0$ holds in the state of $\varphi_J^o = \varphi_A^o = \varphi_C^o = 0$, the Japanese, U.S., or Chinese primary domain is the domain in which $f_J < 1.0$, $f_A > 1.0$, or $f_C < 1.0$ is maintained, respectively. Similarly, the ”reverse domain” is defined as the domain in which the state of output reverses as compared to the primary state as a consequence of the internalization of public benefits. In other words, the Japanese, U.S., or Chinese reverse domain is the domain in which $f_J > 1.0$, $f_A < 1.0$, or $f_C > 1.0$ is maintained, respectively.

Table 7 shows that even if the public benefits before specialization are estimated as $\varphi_J^o < \varphi_A^o$, there is a possibility of $f_J > 1.0$. For example, $\varphi_J^o = 3.0$, $\varphi_A^o = 5.0$ (i.e., from the viewpoint of the rate of labor productivity increments, $q_{GJ} = 4.3$, $q_{GA} = 4.6$) result in $f_J = 1.5$. Table 7(a) and Table 8(a) show that the reverse domain of Japanese forestry is fairly sensitive both to φ_J^o and φ_A^o but is minimally sensitive to φ_C^o.

Figure 4 shows the reverse domains of forestry in each country calculated using the data of 15 aggregated sectors. Figure 5 shows the reverse domains calculated using the data of 14 aggregated sectors. Figure 6 shows the reverse domains for three aggregated sectors, but these results were calculated without the restriction on non-tradable goods (i.e., equation [16]). The reason for removing this restriction was that it is unnatural to impose such restrictions on all tertiary sectors.

$\gamma_{min} = 0.5$, $\gamma_{max} = 1.5$ are set up for every sector in Figures 4-6. Figure 4 shows the results for separate forestry sectors. In contrast, Figures 5, 6 show results for aggregated primary industry sectors. Figure 4 shows that reverse domains in each country exist within the range

Table 7. Impact of public benefits from the forestry sector on the rate of output increase of forestry -φ_J^o:

- ϕ_J^o : ϕ_A^o , $\phi_C^o = 0$, 15 sectors, $\gamma_{\min} = 0.5$, $\gamma_{\max} = 1.5$ -

(a) Rate of output increase of Japanese forestry (f_J)

$\phi_C^O = 0$		ϕ_J^o $(10^{10}\$/\text{year})$ 0.00	0.10	0.20	0.30	0.50	1.00	2.00	3.00	5.00	10.00
	$q_{GA}\downarrow$ $q_{GJ}\rightarrow$	1.00	1.11	1.22	1.33	1.55	2.10	3.19	4.29	6.48	11.97
ϕ_A^o $(10^{10}\$/\text{year})$ 0.00	1.00	0.74	0.74	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
0.10	1.07	0.74	0.74	0.77	1.50	1.50	1.50	1.50	1.50	1.50	1.50
0.20	1.14	0.74	0.74	0.77	0.77	1.50	1.50	1.50	1.50	1.50	1.50
0.30	1.22	0.74	0.74	0.77	0.77	1.50	1.50	1.50	1.50	1.50	1.50
0.50	1.36	0.74	0.74	0.77	0.77	1.50	1.50	1.50	1.50	1.50	1.50
1.00	1.72	0.74	0.74	0.77	0.77	0.77	1.50	1.50	1.50	1.50	1.50
2.00	2.44	0.74	0.74	0.77	0.77	0.77	0.77	1.50	1.50	1.50	1.50
3.00	3.16	0.74	0.74	0.77	0.77	0.77	0.77	1.50	1.50	1.50	1.50
5.00	4.59	0.74	0.74	0.77	0.77	0.77	0.77	0.77	1.50	1.50	1.50
10.00	8.19	0.74	0.74	0.77	0.77	0.77	0.77	0.77	0.77	0.96	1.50

(b) Rate of output increase of U.S. forestry (f_A)

$\phi_C^O = 0$		ϕ_J^o $(10^{10}\$/\text{year})$ 0.00	0.10	0.20	0.30	0.50	1.00	2.00	3.00	5.00	10.00
	$q_{GA}\downarrow$ $q_{GJ}\rightarrow$	1.00	1.11	1.22	1.33	1.55	2.10	3.19	4.29	6.48	11.97
ϕ_A^o $(10^{10}\$/\text{year})$ 0.00	1.00	1.50	1.50	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11
0.10	1.07	1.50	1.50	1.50	1.11	1.11	1.11	1.11	1.11	1.11	1.11
0.20	1.14	1.50	1.50	1.50	1.50	1.11	1.11	1.11	1.11	1.11	1.11
0.30	1.22	1.50	1.50	1.50	1.50	1.11	1.11	1.11	1.11	1.11	1.11
0.50	1.36	1.50	1.50	1.50	1.50	1.11	1.11	1.11	1.11	1.11	1.11
1.00	1.72	1.50	1.50	1.50	1.50	1.50	1.11	1.11	1.11	1.11	1.11
2.00	2.44	1.50	1.50	1.50	1.50	1.50	1.50	1.11	1.11	1.11	1.11
3.00	3.16	1.50	1.50	1.50	1.50	1.50	1.50	1.11	1.11	1.11	1.11
5.00	4.59	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.11	1.11	1.11
10.00	8.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.21

(c) Rate of output increase of Chinese forestry (f_C)

$\phi_C^O = 0$		ϕ_J^o $(10^{10}\$/\text{year})$ 0.00	0.10	0.20	0.30	0.50	1.00	2.00	3.00	5.00	10.00
	$q_{GA}\downarrow$ $q_{GJ}\rightarrow$	1.00	1.11	1.22	1.33	1.55	2.10	3.19	4.29	6.48	11.97
ϕ_A^o $(10^{10}\$/\text{year})$ 0.00	1.00	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
0.10	1.07	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
0.20	1.14	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
0.30	1.22	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
0.50	1.36	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
1.00	1.72	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
2.00	2.44	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
3.00	3.16	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
5.00	4.59	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
10.00	8.19	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50

Note 1) $q_{GJ} \equiv 1 + \phi_J^o / G_{J2}^o$, etc. , $G_{J2}^o = 0.91$, $G_{A2}^o = 1.39$, $G_{C2}^o = 0.76$ $(10^{10}\$/\text{year})$

2) "Primary domain" "Reverse domain"

(a) Rate of output increase of Japanese forestry (f_J), (b) Rate of output increase of U.S. forestry (f_A), (c) Rate of output increase of Chinese forestry (f_C).

Table 8. Impact of public benefits from the forestry sector on the rate of output increase of forestry -φ_J^o:

– $\phi_J^o : \phi_C^o$, ϕ_A^o=0, 15 sectors, γ_{min} = 0.5, γ_{max} = 1.5 –

(a) Rate of output increase of Japanese forestry (f_J)

$\phi_A^O = 0$		ϕ_J^o $(10^{10}\$/\text{year})$: 0.00	0.10	0.20	0.30	0.50	1.00	2.00	3.00	5.00	10.00
	q_{GA} ↓ q_{GJ} →	1.00	1.11	1.22	1.33	1.55	2.10	3.19	4.29	6.48	11.97
ϕ_C^o $(10^{10}\$/\text{year})$: 0.00	1.00	0.74	0.74	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
0.10	1.13	0.50	0.74	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
0.20	1.26	0.50	0.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
0.30	1.39	0.50	0.50	0.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
0.50	1.66	0.50	0.50	0.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1.00	2.31	0.50	0.50	0.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2.00	3.63	0.50	0.50	0.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3.00	4.94	0.50	0.50	0.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
5.00	7.57	0.50	0.50	0.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
10.00	14.13	0.50	0.50	0.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

(b) Rate of output increase of U.S. forestry (f_A)

$\phi_A^O = 0$		ϕ_J^o $(10^{10}\$/\text{year})$: 0.00	0.10	0.20	0.30	0.50	1.00	2.00	3.00	5.00	10.00
	q_{GA} ↓ q_{GJ} →	1.00	1.11	1.22	1.33	1.55	2.10	3.19	4.29	6.48	11.97
ϕ_C^o $(10^{10}\$/\text{year})$: 0.00	1.00	1.50	1.50	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11
0.10	1.13	1.50	1.50	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11
0.20	1.26	1.50	1.50	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11
0.30	1.39	1.15	1.15	1.15	0.60	0.60	0.60	0.60	0.60	0.60	0.60
0.50	1.66	1.15	1.15	1.15	0.60	0.60	0.60	0.60	0.60	0.60	0.60
1.00	2.31	1.15	1.15	1.15	0.60	0.60	0.60	0.60	0.60	0.60	0.60
2.00	3.63	1.15	1.15	1.15	0.60	0.60	0.60	0.60	0.60	0.60	0.60
3.00	4.94	1.15	1.15	1.15	0.60	0.60	0.60	0.60	0.60	0.60	0.60
5.00	7.57	1.15	1.15	1.15	0.60	0.60	0.60	0.60	0.60	0.60	0.60
10.00	14.13	1.15	1.15	1.15	0.60	0.60	0.60	0.60	0.60	0.60	0.60

(c) Rate of output increase of Chinese forestry (f_C)

$\phi_A^O = 0$		ϕ_J^o $(10^{10}\$/\text{year})$: 0.00	0.10	0.20	0.30	0.50	1.00	2.00	3.00	5.00	10.00
	q_{GA} ↓ q_{GJ} →	1.00	1.11	1.22	1.33	1.55	2.10	3.19	4.29	6.48	11.97
ϕ_C^o $(10^{10}\$/\text{year})$: 0.00	1.00	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
0.10	1.13	0.77	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
0.20	1.26	0.80	0.80	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
0.30	1.39	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
0.50	1.66	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1.00	2.31	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2.00	3.63	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3.00	4.94	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
5.00	7.57	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
10.00	14.13	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

Note 1) $q_{GJ} \equiv 1 + \phi_J^o / G_{J2}^o$, etc., G_{J2}^o=0.91, G_{A2}^o=1.39, G_{C2}^o=0.76 $(10^{10}\$/\text{year})$

2) "Primary domain" "Reverse domain"

(a) Rate of output increase of Japanese forestry (f_J), (b) Rate of output increase of U.S. forestry (f_A), (c) Rate of output increase of Chinese forestry (f_C).

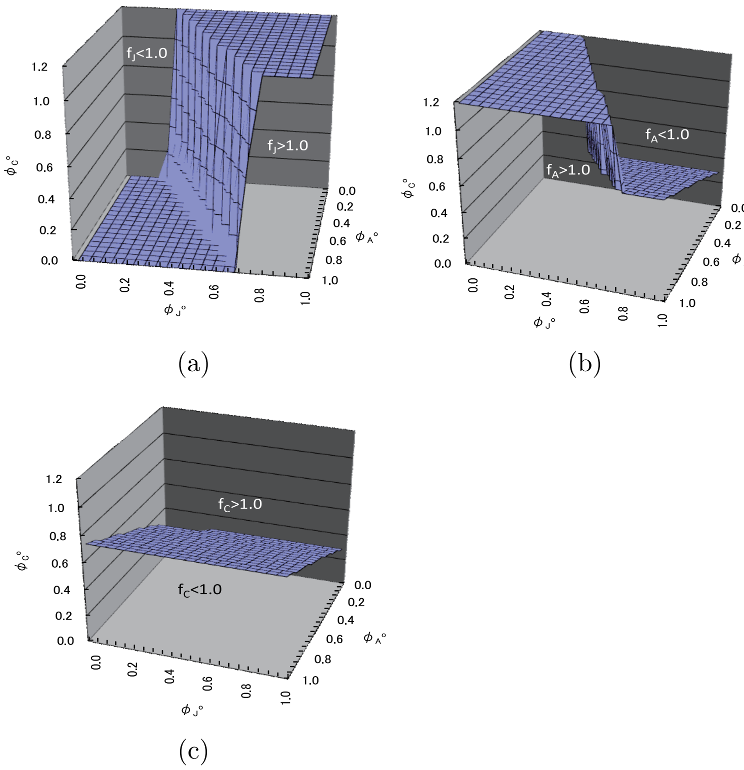
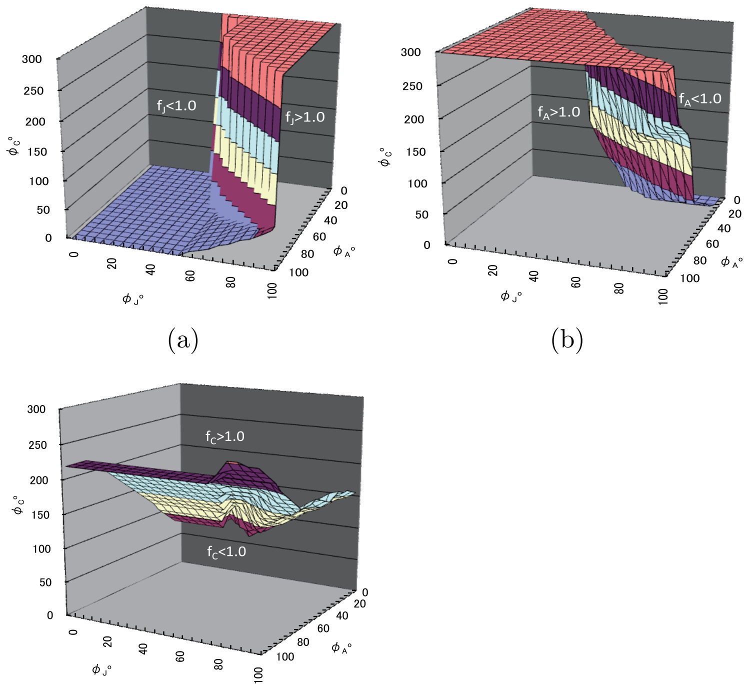


Figure 4. “Reverse Domain” of Japanese, U.S.’s, Chinese Forestry -for 15 sectors-

(a) Japanese Forestry, (b) U.S.’s Forestry, (c) Chinese Forestry.

of $\varphi_J^o = 0 - 1.0$, $\varphi_A^o = 0 - 1.0$, $\varphi_C^o = 0 - 1.0$ (10^{10} \$/year). Figure 4 (a) also shows that the Japanese reverse domain is fairly sensitive to both φ_J^o and φ_A^o but is minimally sensitive to φ_C^o. Figure 4 (c) shows that that the Chinese reverse domain is fairly sensitive to φ_A^o but is minimally sensitive to φ_J^o.

Figure 5 shows that the reverse domains for the primary sectors in each country exist within the range of $\varphi_J^o = 0-70$, $\varphi_A^o = 0-70$, $\varphi_C^o =$



(a) (b)

(c)

Figure 5. "Reverse Domain" of Japanese, U.S.'s,
Chinese primary sector -for 14 sectors-

(a) Japanese primary sector, (b) U.S.'s primary sector, (c) Chinese primary sector.

$0-200$ (10^{10} \$/year). Figure 5 (a) also shows that the Japanese reverse domain is fairly sensitive to both φ_J^o and φ_A^o but is minimally sensitive to φ_C^o. Figure 6 shows that the reverse domains for the primary sectors in each country exist within the range of $\varphi_J^o = 0 - 90$, $\varphi_A^o = 0 - 40$, $\varphi_C^o = 0 - 250$ (10^{10} \$/year).

6. Conclusions

This paper pointed out the following. When the public benefit pro-

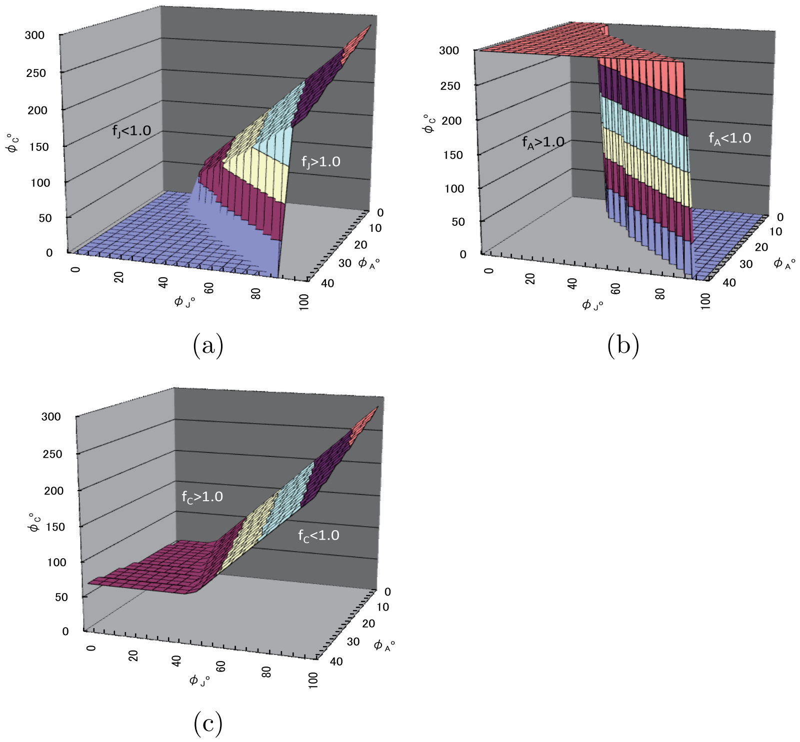


Figure 6. "Reverse Domain" of Japanese, U.S.'s, Chinese primary sector -for 3 sectors-

(a) Japanese primary sector, (b) U.S.'s primary sector, (c) Chinese primary sector.

vided by the forestry sector is not considered at all, no matter what the values of parameter γ_{Kimin}, γ_{Kimax}, and no matter how the sectors are aggregated, it is economically desirable that Japan and China decrease their forestry output and the U.S. increase its output. When the public benefit provided by the forestry sector is considered, no matter what the values of parameter γ_{Kimin}, γ_{Kimax}, Japanese "reverse domain" exists within the range of $\varphi_J^o = 0 - 1.0$ (10^{10} \$/year) in $\varphi_J^o - \varphi_A^o - \varphi_C^o$ spaces.

The shape of the Japanese "reverse domain" described above strongly depends on the value of φ_A^o, but is almost independent of the value of φ_C^o. When the agriculture, forestry and fishery sectors are aggregated to one sector and public benefits from this sector are lumped together, no matter what the values of parameter γ_{Kimin}, γ_{Kimax}, Japanese "reverse domain" exists within the range of $\varphi_J^o = 0 - 70$ (10^{10} \$/year) in $\varphi_J^o - \varphi_A^o - \varphi_C^o$ spaces. The shape of the "reverse domain" of each country depends not only on whether forestry and other primary industries are aggregated but also on how the other sectors are aggregated.

The model presented here succeeds in formulating the supply and demand conditions for each good in the world market using a combination of the Ricardian model and input-output data. That is to say, this model has a good command of international input-output data and succeeds in identifying the reverse domain.

Arbitrary factors inevitably affect the evaluation of public benefits and therefore lessen the value of this model for practical use. However, this model is an effective tool for evaluating the extent to which labor productivity must be increased to increase the self-sufficiency of forestry or other primary industries in the context of policy change (Ejiri, 1999b, 1997, Min, 2008). This method is also useful for econometrically analyzing the trade of forest products within a global market (Yukutake *et al.*, 2003, Yukutake *et al.*, 2006, Yukutake *et al.*, 2007, Yoshimoto *et al.*, 2002), especially when the proposed model is evaluated in terms of the general equilibrium theory. It could also be useful for evaluating the construction of a spatial equilibrium model (Shimamoto, 2002).

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中間財を含む線形貿易モデルによる林業の特化パターン逆転領域の特定

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要約: 最初に, 中間財を含む多数国多数財貿易モデルを, 世界市場内の国々の GDP の総額を最大化する線形計画問題として定式化した．これは, 筆者が以前に作成したモデルを改良したものである．主な改良点は, 各財の最終需要量を当該国の GDP に線形依存するとみなして, 世界市場における各財の需給均衡条件を厳密に定式化した点にある．次いで, 各国の林業の特化パターンが現状より反転するパラメータ φ^o_K (φ^o_K: 現在の生産額を前提とした場合の, K 国の林業によって供給される公益的機能の貨幣価値換算額を表すパラメータ）の領域を, 3 次元 φ^o_K 空間内に特定した．各国の林業が供給する公益的機能の大きさの貨幣価値換算額は, 当該国の林業の生産額に比例すると仮定した．計算には「2000 年アジア国際産業連関表」のデータを用いた．日本, 米国および中国の 3 ヶ国に対する計算結果により, 1) これらの国々の林業の公益的機能を全く勘案しない場合は日本の林業は生産額を現在よりも減少させることが望ましい, 2) この公益的機能を勘案する場合は, 日本の林業の特化パターンが反転する領域が, 3 次元 φ^o_K 空間内の $\varphi^o_J = 0 \sim 1.0$ (10^{10}\$/年) 程度の範囲内に確かに存在する, 3) 農林水産業全体を 1 つの部門に統合し, この産業全体がもたらす公益的機能を一括して評価した場合は, 日本の農林水産業の特化パターンが反転する領域が, 同空間内の $\varphi^o_J = 0 \sim 70$ (10^{10}\$/年) 程度の範囲内に存在する, 等の事実が明らかになった.

キーワード: アジア国際産業連関表, 多数財線形貿易モデル, リカードモデル, 公益的機能, 林業