An empirical study on interdependency of environmental load and international IO structure in the Asia-Pacific region

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1. Introduction

The First Commitment Period of "Kyoto Protocol" of the global warming prevention has started this year 2008, and the concern for the global warming prevention has been rising in Japan. However, it is already obvious that it is impossible to achieve the reduction obligation of Japan stated in the Kyoto Protocol only by domestic measures, and the use of flexible measures (for instance, environmental cooperation of Japan and the developing country such as CDM) becomes a matter of importance. Moreover, the global warming is exactly the problem to work on globally toward solution, and at the same time the emission control of greenhouse gas (GHG) in not only advanced industrial countries but also in developing countries is also a crucial problem.

It is extremely important to understand Input-Output structure (I-O structure) between each country in addition to the industrial structure within the country in order that the advanced countries and developing countries cooperate in the environmental issue and also that the developing countries do the emission control of GHG. For the production of any goods it is necessary to use natural resources including energy and the raw materials (intermediate input goods). If most of such input goods should be domestic goods, the environmental load concerning the production will occur domestically, however, in recent days of globalized economy the imported intermediate inputs become common and it has become usual that the production process of the goods occurs in two or more countries. In other word, the production of the goods of a certain country induces goods production in other countries, and the environmental load occurred in such countries are involved. This is the concept of "embodied environmental load" or "direct & indirect environmental load". Along with the progress of the globalization of the economy, relation between trade and environment became an important issue for discussion of global environmental concerns.

If we focus our attention on energy consumption, we can see that while some countries achieve high growth by exporting the industrial products with large environmental load (i.e., energy-intensive products), on the other hand there are countries that transfer the production activity with high environmental load outside the countries to disguise their domestic environmental load smaller (in other words, to disguise their domestic CO2 emission smaller). Generally, the importing country of

goods (consuming country) transfers the environmental load occurred during production process to the production country so that the environmental load of the importing country is undervalued. There arise differing views depending on to which the "embodied environmental load" occurred directly/indirectly during the production process of goods should be attributed either production country or consuming country. While there is a bitter confrontation between advanced countries and developing countries as for countermeasures against global warming, it would be led to solution if we consider the relation of mutual dependence of the environmental load occurred from trade.

Actually, a similar concept to the energy consumption can be introduced also to the use of water resource and land resource. For instance, though food self-supporting ratio of Japan is low, we can see that by importing agricultural products from abroad Japanese use the land in foreign countries and consume water resources abroad indirectly so that they transfer the environmental load to foreign countries that much.

Among the studies that share our awareness of the issue covering the Pacific Ocean Rim are Imura et al.(2005) and Na(2006). Our study is an extension of those studies, however we include the latest data (that of the year 2000) in the object of the analysis and extend to land use and consumption of water resource as factors of environmental load.

The analysis technique is a standard input-output analysis model. The input-output analysis is the technique to get the amount of production of the goods ultimately required in order to supply the final demand of a certain industry. If the production of final demand is given, we can estimate the energy consumption and the amount used of the natural resources input directly and indirectly in each stage of the production.

In our estimate results, the following has been found. While the United States, China and Japan rank top 3 as for the total amount of energy consumption and CO2 emission in the Asia-Pacific region, China has by far the largest growth in 15 years. The USA and Japan in the 1980s are production places of goods (exporting countries) and at the same time the consuming places (importing countries). In other words, both the USA and Japan carried CO2 emission load in place of other countries, and at the same time they made other countries to carry their own CO2 emission load. However, it is found that in 2000 the role as the consuming place of goods (country to use other countries' energy) was prominent in Japan and the USA. On the other hand,

China has changed from the importing country of goods to exporting country and its role to carry CO2 emission load in place of other countries has been strengthened.

Moreover, we estimated the amount of direct and indirect use of land and water just for agricultural use only. Interestingly in 1985 Japan had already used more land in foreign countries than the land used domestically. However, Japan's amount of land usage is smaller than those of the USA and China as for absolute amount at that time. Japan's "Land use" in China increased thereafter, and in 2000 Japan's indirect amount of land usage in China had expanded so much as the size almost equaled to that in the USA.

2. Data and Model

2-1 Data

The data used in this study is listed the in the references of statistical data at the end of the paper. The explanation of the content is added here.

(1) International Input-Output (I-O) Table

An Asian international input-output table is compiled by Bureaus of Statistics of countries of Asia Pacific Ocean region and the project is headed by Institute of Developing Economies of Japan. The tables of the year 2000, 1995, 1990 and 1985 have been published. The regions covered (endogenous countries) are 10 countries/regions, i.e. Indonesia, Malaysia, the Philippines, Singapore, Thailand, China, Taiwan, South Korea, Japan, and the United States.

Figure 1 shows the schematic image of Asian international input-output table. When the rows of the table are seen, we can see how much of the produced goods are sold to which country/region. The intermediate demand block and the final demand block are listed by country in the same order as stated above (Indonesia, Malaysia…the United States) and the column at the right end shows those total, i.e. the total of the domestic output. In a usual one country table, if the concerned goods cross border between countries, it is treated as final demand as "export". However, in international I-O table the export of intermediate goods for endogenous countries is treated as a part of the endogenous sector, and "export as final goods for endogenous countries" and "export for exogenous countries" only are calculated as export. On the other hand, when the table is read in the direction of column, we can see how much input is occurred from which country/region to produce goods. They are listed by country in the same order as stated above (Indonesia, Malaysia…the United States)

and the value added is calculated and listed under that. The row at the very bottom is the total of those, i.e. the total input. Since international fare and the export insurance are difficult to tell which country's service, so they are calculated aside

Though Asian international input-output table has 24-industrial sectors, it is not corresponding to the industrial classification of the energy statistics described in the next section. To ensure consistency with the input-output table and the energy statistics, we integrated them into the 13 sectors as shown in Table 1 based on the classification of Imura et al (2005).

(2) The Factor of Environmental Load

In this research, we treat the following three kinds as environmental load: (i)the Amount of energy consumption and CO2 emissions, (ii) Land use for agriculture, and (iii) Consumption of water resource for agriculture.

First, as for the amount of energy consumption, we used the statistics from energy balance table (World Energy Statistics and Balances) that IEA (world energy organization) publishes. In this statistics, the energy balance data of ten countries/regions i.e. Indonesia, Malaysia, the Philippines, Singapore, Thailand, China, Taiwan, South Korea, Japan, and the United States is obtained by calorie (TOE) base.

The energy covered are Coal, Petroleum and Natural Gas, however, crude oil and petroleum products were integrated and treated as "Petroleum" for the simplification. The allotment with industries in the energy balance table is corresponded as shown in the following table.

Figure1 Table structure of IDE International Input-Output table

		Intermediate Demand (A)										Final Demand (F)										Export (L)				
		Indonesia	Malaysia	Philippines	Singapore	Thailand	China	Taiwan	Korea	Japan	U.S.A	Indonesia	Malaysia	Philippines	Singapore	Thailand	China	Taiwan	Korea	Japan	U.S.A	Export to Hong Kong	Export to EU	Export to R.O.W.	Statistical Discrepancy	Total Outputs
	code	(AI)	(AM)	(AP)	(AS)	(AT)	(AC)	(AN)	(AK)	(AJ)	(AU)	(FI)	(FM)	(FP)	(FS)	(FT)	(FC)	(FN)	(FK)	(FJ)	(FU)	(LH)	(LO)	(LW)	(QX)	(XX)
Indonesia	(AI)	A^{II}	A^{IM}	A^{IP}	A^{IS}	A^{IT}	A^{IC}	A^{IN}	A^{IK}	A^{IJ}	A^{IU}	F^{II}	F^{IM}	F^{IP}	F^{IS}	F^{IT}	F^{IC}	F^{IN}	F^{IK}	F^{IJ}	F^{IU}	L^{IH}	L^{IO}	L^{IW}	Q^{I}	X^{I}
Malaysia	(AM)	A^{MI}	A^{MM}	A^{MP}	A^{MS}	A^{MT}	A^{MC}	A^{MN}	A^{MK}	A^{MJ}	A^{MU}	F^{MI}	F^{MM}	F^{MP}	F^{MS}	F^{MT}	F^{MC}	F^{MN}	F^{MK}	F^{MJ}	F^{MU}	L^{MH}	L^{MO}	L^{MW}	Q^{M}	X^{M}
Philippines	(AP)	A^{PI}	A^{PM}	A^{PP}	A^{PS}	A^{PT}	A^{PC}	A^{PN}	A^{PK}	A^{PJ}	A^{PU}	F^{PI}	F^{PM}	F^{PP}	F^{PS}	F^{PT}	F^{PC}	F^{PN}	F^{PK}	F^{PJ}	F^{PU}	L^{PH}	L^{PO}	L^{PW}	Q^{P}	X^{P}
Singapore	(AS)	A^{SI}	A^{SM}	A^{SP}	A^{SS}	A^{ST}	A^{SC}	A^{SN}	A^{SK}	A^{SJ}	A^{SU}	F^{SI}	F^{SM}	F^{SP}	F^{SS}	F^{ST}	F^{SC}	F^{SN}	F^{SK}	F^{SJ}	F^{SU}	L^{SH}	L^{SO}	L^{SW}	Q^{S}	X^{S}
Thailand	(AT)	A^{TI}	A^{TM}	A^{TP}	A^{TS}	A^{TT}	A^{TC}	A^{TN}	A^{TK}	A^{TJ}	A^{TU}	F^{TI}	F^{TM}	F^{TP}	F^{TS}	F^{TT}	F^{TC}	F^{TN}	F^{TK}	F^{TJ}	F^{TU}	L^{TH}	L^{TO}	L^{TW}	Q^{T}	X^{T}
China	(AC)	A^{CI}	A^{CM}	A^{CP}	A^{CS}	A^{CT}	A^{CC}	A^{CN}	A^{CK}	A^{CJ}	A^{CU}	F^{CI}	F^{CM}	F^{CP}	F^{CS}	F^{CT}	F^{CC}	F^{CN}	F^{CK}	F^{CJ}	F^{CU}	L^{CH}	L^{CO}	L^{CW}	Q^{C}	X^{C}
Taiwan	(AN)	A^{NI}	A^{NM}	A^{NP}	A^{NS}	A^{NT}	A^{NC}	A^{NN}	A^{NK}	A^{NJ}	A^{NU}	F^{NI}	F^{NM}	F^{NP}	F^{NS}	F^{NT}	F^{NC}	F^{NN}	F^{NK}	F^{NJ}	F^{NU}	L^{NH}	L^{NO}	L^{NW}	Q^{N}	X^{N}
Korea	(AK)	A^{KI}	A^{KM}	A^{KP}	A^{KS}	A^{KT}	A^{KC}	A^{KN}	A^{KK}	A^{KJ}	A^{KU}	F^{KI}	F^{KM}	F^{KP}	F^{KS}	F^{KT}	F^{KC}	F^{KN}	F^{KK}	F^{KJ}	F^{KU}	L^{KH}	L^{KO}	L^{KW}	Q^{K}	X^{K}
Japan	(AJ)	A^{JI}	A^{JM}	A^{JP}	A^{JS}	A^{JT}	A^{JC}	A^{JN}	A^{JK}	A^{JJ}	A^{JU}	F^{JI}	F^{JM}	F^{JP}	F^{JS}	F^{JT}	F^{JC}	F^{JN}	F^{JK}	F^{JJ}	F^{JU}	L^{JH}	L^{JO}	L^{JW}	Q^{J}	X^{J}
U.S.A.	(AU)	A^{UI}	A^{UM}	A^{UP}	A^{US}	A^{UT}	A^{UC}	A^{UN}	A^{UK}	A^{UJ}	A^{UU}	F^{UI}	F^{UM}	F^{UP}	F^{US}	F^{UT}	F^{UC}	F^{UN}	F^{UK}	F^{UJ}	F^{UU}	L^{UH}	L^{UO}	L^{UW}	Q^{U}	X^{U}
Freight and Insurance	(BF)	BA^{I}	BA^{M}	BA^{P}	BA^{S}	BA^{T}	BA^{C}	BA^{N}	BA^{K}	BA^{J}	BA^{U}															
Import from Hong Kor	(CH)	A^{HI}	A^{HM}	A^{HP}	A^{HS}	A^{HT}	A^{HC}	A^{HN}	A^{HK}	A^{HJ}	A^{HU}															
Import from EU	(CO)	A^{OI}	A^{OM}	A^{OP}	A^{OS}	A^{OT}	A^{OC}	A^{ON}	A^{OK}	A^{OJ}	A^{OU}															
Import from the R.O.W	(CW)	A^{WI}	A^{WM}	A^{WP}	A^{WS}	A^{WT}	A^{WC}	A^{WN}	A^{WK}	A^{WJ}	A^{WU}															
Duties and Import Commodity Taxes	(DT)	DA^{I}	DA^{M}	DA^{P}	DA^{S}	DA^{T}	DA^{C}	DA^{N}	DA^{K}	DA^{J}	DA^{U}															
Value Added	(VV)	V^{I}	V^{M}	V^{P}	V^{S}	V^{T}	V^{C}	V^{N}	V^{K}	V^{J}	V^{U}															
Total Inputs	(XX)	X^{I}	X^{M}	X^{P}	X^{S}	X^{T}	X^{C}	X^{N}	X^{K}	X^{J}	X^{U}															

Source: http://www.ide.go.jp/Japanese/Publish/Books/Tokei/xls/AIO(85-00).xls

Table 1 Industry aggregation in this study

	Original industry classification in IDE Asian I-O table		Industry classification in this study
01	Paddy	01	Primary industry
02	Other agricultural products*		
03	Livestock		
04	Forestry		
05	Fishery		
06	Crude petroleum and natural gas	02	Mining
07	Other mining		
08	Food, beverage and tobacco	03	Food, beverage and tobacco
09	Textile, leather and the products thereof	04	Textile and leather products
10	Timber and wooden products	05	Timber and wooden products
11	Pulp, paper and printing	06	Pulp & Paper products
12	Chemical products	07	Chemical & Non-metallic mineral products
13	Petroleum and petro products		
14	Rubber products		
15	Non-metallic mineral products		
16	Metal products	08	Metal products
17	Machinery	09	Machinery
18	Transport equipment		
19	Other manufacturing products		
20	Electricity, gas, and water supply	10	Electricity, gas, and water supply
21	Construction	11	Construction
22	Trade and transport	12	Transportation
23	Services	13	Other Services
24	Public administration		

Table 2 Energy using industry aggregation in this study

IEA Classification	Classification in this study
Energy Transfer Sector	Energy Transfer Sector
Transfer	neglected
Statistical Discrepancy	neglected
Electricity Plants	10 Electricity, gas, and water supply
HCP Plants	
Heat plants	
Gas works	
Petroleum refineries	07 Chemical & Non-metallic mineral products
Coal transformation	
Liquefaction Plants	
Other transformation	
Own use	
Distribution Losses	
Energy consumption Sector	Energy consumption Sector
Iron and Steel	08 Metal products
Non-ferrous metal	
Chemical and Petrochemical	07 Chemical & Non-metallic mineral product
Non-metallic minerals	
Transport equipment	09 Machinery
Machinery	
Mining and quarrying	02 Mining
Food and tobacco	03 Food, beverage and tobacco
Paper Pulp and Printing	06 Pulp & Paper products
Wood and Wood products	05 Timber and wooden products
Non-specified	09 Machinery
Construction	11 Construction
Textile and leather	04 Textile and leather products
Transport sector	12 Transportation
Agriculture	01 Primary industry
Comm. and Publ. services	13 Other Services
Residential	neglected

Table 3 C02 content of each energy

	CO2 (ton/toe)	Carbon (ton/toe)
Coal	4.018	1.096
Petroleum	3.313	0.903
Natural Gas	2.317	0.632

Source: The Institute of Energy Economics, Japan, *2008 EDMC Handbook of Energy & Economic Statistics in Japan*

As for CO2 emission there is a stable relation between the amount of consumed calorie (amount of calorie) of fossil fuel and the amount of emission of carbon dioxide. Table 3 shows the coefficient. Coal has largest amount of CO2 generation per consumed calorie and on the other hand natural gas has smallest amount of CO2 generation among fossil fuels.

We used data base FAOSTAT of UN Food and Agriculture Organization (FAO) as for the use of land and of water resource. However, the data base of FAOSTAT is limited to the data of the land use and the water resource use for agriculture and the livestock industry because of its nature. Therefore, this study covers only the land use and water resource use by agriculture and livestock industry only, so that it is to be noted that the results obtained here are "import and export" of land resource and water resource related to agriculture and the livestock industry.

2-2 Model

The main source of global warming is CO2 emissions accompanied with fossil energy consumption. In thinking of emission origins of CO2, there are such three manners as (0) fossil energy production criterion, (1) fossil energy consumption criterion and (2) final goods consumption criterion. As a matter of fact, "(0) fossil energy production criterion" is not realistic since this criterion attributes the global warming to only fossil energy producing countries. The criterion that Kyoto protocol adopts is "(1) fossil energy consumption criterion". This criterion set a focus on the production process, or, direct environmental lead. In spite of that, as is mentioned in the introduction, it also possible to say that the true CO2 emitter is not a producer side but a consumer side since any goods are produce to consume and energy is used to produce any kinds of goods. This is the philosophy of "(2) final goods consumption criterion", or, direct & indirect environmental lead. This philosophy can be applied to land usage and water consumption in producing agricultural goods. An importer of agricultural goods indirectly uses the land of the exporter though the exporter cultivates its own land and an importer of agricultural goods indirectly uses the water of the exporter though the exporter makes use of its own water. Especially, direct & indirect water usage is called "vertical water consumption". This section summarizes a calculation method of direct and indirect environmental load.

In the one-country I-O model, the following supply-demand relation holds between the final demand for domestic goods ($\mathbf{f}^{\mathbf{d}}$) and domestic supply($\mathbf{x}$).

$$\mathbf{x} = \mathbf{A}^{\mathbf{d}}\mathbf{x} + \mathbf{f}^{\mathbf{d}} \quad (1)$$

The matrix $\mathbf{A}^{\mathbf{d}}$ is the domestic input coefficient matrix each column of which shows the directly required quantity of domestically produces intermediate inputs in order to produce one unit of the corresponding output. Incidentally, the import from abroad (**m**) is defined as the total of the intermediate demand and final demand($\mathbf{f}^{\mathrm{m}}$).

$$\mathbf{m} = \mathbf{A}^{\mathbf{m}}\mathbf{x} + \mathbf{f}^{\mathbf{m}} \quad (1')$$

The matrix $\mathbf{A}^{\mathbf{m}}$ is the import input coefficient matrix each column of which shows the directly required quantity of imported intermediate inputs in order to produce one unit of the corresponding output.

Solving Eq. (1) in terms of domestic output(**x**), the following equilibrium output determination equation is derived. Matrix B is known as the inverse matrix of Leontief.

$$\mathbf{x} = (\mathbf{I} - \mathbf{A}^{\mathbf{d}})^{-1}\mathbf{f}^{\mathbf{d}} = \mathbf{B}\mathbf{f}^{\mathbf{d}} \quad (2)$$

Here, let a vector '**a**' be an input coefficient of such resources as energy, land, or water[1]. Multiplying resource input coefficient '**a**' and domestic output (**x**), the 'Direct 'Environmental Load' ($\mathbf{El}_d$) in the fossil energy consumption criterion is derived as follows.

$$\mathbf{El}_d = \mathbf{a}\hat{\mathbf{x}} = \mathbf{a}\begin{bmatrix} x_1 & & \\ & \ddots & \\ & & x_n \end{bmatrix} \quad (3)$$

On the other hand, in order to obtain direct & indirect environmental load ($\mathbf{El}_{did}$) in the final goods consumption criterion is calculated as follows.

$$\mathbf{El}_{did} = \mathbf{a}\mathbf{B}\begin{bmatrix} f_1^d & & \\ & \ddots & \\ & & f_n^d \end{bmatrix} \quad (4)$$

CO2 emissions are proportional to calorie based energy consumption, then, CO2 emission by industry can be calculated by multiplying CO2 emission coefficient (in

[1] Since this research considers three kinds of fossil energies, there also are three kinds of input coefficient of energies such as coal, petroleum, and natural gas.

Table 3) and energy consumption obtained in Eq. (3) or Eq. (4)

The model is so far for one country I-O table, but this model can be extended for multi countries/regions I-O tables. Let's use bi-regional I-O table in the explanation for a simplification. The following supply-demand relation holds in both region1 and region 2.

$$\begin{bmatrix}\mathbf{x_1}\\ \mathbf{x_2}\end{bmatrix}=\begin{bmatrix}\mathbf{A_{11}} & \mathbf{A_{12}}\\ \mathbf{A_{21}} & \mathbf{A_{22}}\end{bmatrix}\begin{bmatrix}\mathbf{x_1}\\ \mathbf{x_2}\end{bmatrix}+\begin{bmatrix}\mathbf{f_{11}}+\mathbf{f_{12}}+\mathbf{f_{13}}\\ \mathbf{f_{21}}+\mathbf{f_{22}}+\mathbf{f_{13}}\end{bmatrix} \qquad (1'')$$

The suffix 1 and 2 stands for a region. $\mathbf{A}_{ij}$ stands for a input coefficient, where if $i=j$ it is the intra-country input coefficient and if $i\neq j$ it is the input coefficient for inputs in i region to produce goods in j region. As to final demand $\mathbf{f}_{ij}$, if $i=j$ it is the own country's final demands and if $i\neq j$ it is the final demands for i region by j region. $\mathbf{f}_{i3}$, however, stands for the export from region i to ROW (the Rest of the World). Take a look at Figure 1, a column bordered with thick lines corresponds to the domestic output **x** and columns bordered with double lines correspond to the final demands **f**.

$$\begin{bmatrix}\mathbf{x_1}\\ \mathbf{x_2}\end{bmatrix}=\left[\mathbf{I}-\begin{bmatrix}\mathbf{A_{11}} & \mathbf{A_{12}}\\ \mathbf{A_{21}} & \mathbf{A_{22}}\end{bmatrix}\right]^{-1}\begin{bmatrix}\mathbf{f_{11}}+\mathbf{f_{12}}+\mathbf{f_{13}}\\ \mathbf{f_{21}}+\mathbf{f_{22}}+\mathbf{f_{23}}\end{bmatrix}=\begin{bmatrix}\mathbf{B_{11}} & \mathbf{B_{12}}\\ \mathbf{B_{21}} & \mathbf{B_{22}}\end{bmatrix}\begin{bmatrix}\mathbf{f_1}\\ \mathbf{f_2}\end{bmatrix} \qquad (2')$$

'Direct 'Environmental Load' ($\mathbf{El}_d$) in the fossil energy consumption criterion is expressed as follows based on multi-region I-O table.

$$\mathbf{El}_d=\begin{bmatrix}\mathbf{a_1} & \mathbf{a_2}\end{bmatrix}\left[\begin{array}{c|c}\hat{\mathbf{x}}_1 & \mathbf{0}\\ \hline \mathbf{0} & \hat{\mathbf{x}}_2\end{array}\right] \qquad (3')$$

And direct & indirect environmental load ($\mathbf{El}_{did}$) of the final goods consumption by i country is expressed as follows.

$$\mathbf{El}_{did}=\begin{bmatrix}\mathbf{a_1} & \mathbf{a_2}\end{bmatrix}\begin{bmatrix}\mathbf{B_{11}} & \mathbf{B_{12}}\\ \mathbf{B_{21}} & \mathbf{B_{22}}\end{bmatrix}\left[\begin{array}{c|c}\hat{\mathbf{f}}_{1i} & \mathbf{0}\\ \hline \mathbf{0} & \hat{\mathbf{f}}_{2i}\end{array}\right] \qquad (4')$$

3. Calculation Results

In this section, we show the transaction of energy, CO2, land and water embodied in goods and services traded in the Asia-Pacific region, calculated based on the equation (4'), for the years of 1985 and 2000.

3-1 Embodied energy transaction

Table 4 and 5 shows the embodied energy transaction in 1985 and 2000. Columns are the regions that generated final demands. Rows are the countries where energy consumption is induced by the column regions' final demand. For instance, the figure '16.1' in the intersection of the USA's column and Japan's row shows that final demand in the USA induced 16.1 million toe energy consumption in Japan. On the other hand the filgure'9.4' in the intersection of Japan's column and the USA's row shows that final demand in the USA induced 6.4 million toe energy consumption in the USA. This means that the USA indirectly imported energy for 16.1 million toe form Japan and Japan indirectly imported energy for 9.4 million toe from the USA. As a result, Japan has a 'trade surplus' by 5.7 million toe against the USA in terms of energy

Each value in the column at the right end shows the total amount of energy consumption of each row country. We shaded the following three types of cells; the diagonal element, the top 10 in the off diagonal elements and the top 3 as to the total energy consumption.

Table 4 Embodied Energy Transactions in 1985 (unit: million toe)

	In	Ma	Ph	Si	Th	Ch	Ta	Ko	JPN	USA	ROW	Total
Indonesia	21.0	0.1	0.1	0.2	0.0	0.1	0.0	0.1	1.2	0.8	1.3	25.0
Malaysia	0.0	6.3	0.1	0.3	0.1	0.1	0.0	0.1	0.4	1.3	2.7	11.5
Philippines	0.0	0.1	6.7	0.0	0.0	0.0	0.0	0.0	0.3	0.7	1.0	8.9
Singapore	0.2	0.3	0.0	2.2	0.1	0.0	0.0	0.0	0.4	0.5	3.8	7.6
Thailand	0.0	0.1	0.0	0.0	11.2	0.1	0.0	0.0	0.3	0.4	2.6	14.7
China	0.4	0.5	0.4	1.1	0.5	367.6	0.1	0.1	7.1	6.2	27.3	411.2
Taiwan	0.1	0.1	0.0	0.1	0.1	0.3	12.1	0.1	0.9	4.9	4.0	22.8
Korea	0.1	0.1	0.1	0.1	0.1	0.0	0.1	22.3	1.3	3.6	7.0	34.6
Japan	0.8	0.5	0.1	0.5	0.6	4.0	0.8	1.4	241.4	16.1	25.0	291.2
USA	0.8	0.7	0.3	0.7	0.4	2.3	1.29	2.1	9.4	1,343.9	104.1	1,466.1
Total	23.4	8.7	7.7	5.3	13.0	374.6	14.4	26.2	262.7	1,378.5	178.9	2,293.5

First, let's take a look at the total energy consumption in 1985. The top 3 countries in total energy consumption are the United States (1.5 billion toe), China (0.4 billion toe), and Japan (0.3 billion toe), respectively. Though this order does not change in 2000 (table 5), the increase in China was especially large of 2.1 times while that in the United States and Japan was 1.3 times and 1.1 times, respectively.

As far Japan and the United States, these two countries have similar

characteristics. In 1985, they induced large energy consumptions in other countries and large energy consumptions in them were concurrently induced by other countries. As a matter of fact, all shaded off-diagonal cells in table 4 are for the United States or Japan. However, the situation in 2000 has changed for the USA and Japan to induce much more energy consumptions in other countries than that induced by other countries.

As to China, the ratio of energy consumption induced by the final demand in other countries has doubled from 10.6% in 1985 to 23.4% in 2000. Since the corresponding ratio for Japan and the United States in 2000 respectively is 12.2% and 10.3%, we can tell how China's 'energy exporting ratio' is large. China has become a "factory in the Asia-Pacific region" in 2000.

Table 5 Embodied Energy Transactions in 2000 (unit: million toe)

	In	Ma	Ph	Si	Th	Ch	Ta	Ko	Ja	US	ROW	Total
Indonesia	61.5	0.8	0.4	0.7	0.7	1.7	0.9	1.4	5.3	6.5	17.8	97.7
Malaysia	0.4	17.4	0.4	1.6	0.6	1.6	0.8	0.7	3.9	7.7	16.7	51.8
Philippines	0.0	0.1	14.0	0.0	0.1	0.2	0.2	0.2	1.0	2.3	3.7	21.9
Singapore	0.2	0.5	0.3	6.1	0.3	0.8	0.4	0.3	0.7	1.6	10.7	21.8
Thailand	0.2	0.4	0.2	0.4	33.5	0.8	0.4	0.3	2.5	4.0	13.5	56.1
China	1.2	1.3	0.5	1.4	1.6	650.9	2.6	5.2	27.6	52.4	105.1	849.7
Taiwan	0.2	0.3	0.2	0.2	0.4	4.0	40.5	0.4	2.3	5.7	16.0	70.3
Korea	0.6	0.4	0.4	0.3	0.4	5.6	1.1	103.0	5.3	8.3	30.0	155.3
Japan	0.4	0.6	0.2	0.6	0.7	2.4	1.5	1.4	274.7	10.0	20.6	313.1
USA	0.6	0.9	0.5	0.9	0.9	4.1	3.2	3.8	13.4	1,658.6	161.7	1,848.6
Total	65.3	22.6	17.1	12.2	39.2	672.2	51.6	116.6	336.8	1,757.0	395.8	3,486.4

3-2 Embodied CO2 transaction

Table 6 and 7 show the embodied CO2 transactions in 1985 and 2000, respectively. Since CO2 emissions are calculated by multiplying energy consumptions by emission coefficient showed in table 3 and 4, the results is expected to be similar to the case for the embodied energy transaction.

In fact, the United States, China and Japan rank top 3 as to the total CO2 emissions, and the increase in CO2 emissions in China was extremely large during 15 years. Japan and the United States carried CO2 emission load in place of other countries in 1985, and at the same time they made other countries to carry their own CO2 emission load. On the other hand, in 2000, the both countries only made other countries to carry their own CO2 emission load. In other words, they shifted their

position from “factory place” to “consuming place” of goods. As for China, 23.4% CO2 emission was induced by overseas final demand in 2000. This figure is large comparing with 12.5% for Japan and 10.1% for the United States. China has become a “surrogate CO2 emitter” in 2000.

Table 6 Embodied CO2 Transactions in 1985 (unit: million ton)

	In	Ma	Ph	Si	Th	Ch	Ta	Ko	Ja	US	ROW	Total
Indonesia	64.9	0.2	0.2	0.6	0.1	0.4	0.1	0.2	3.5	2.4	3.9	76.4
Malaysia	0.1	20.0	0.3	1.0	0.2	0.2	0.1	0.3	1.4	4.1	8.2	35.9
Philippines	0.0	0.3	22.9	0.1	0.1	0.1	0.1	0.1	1.0	2.4	3.5	30.6
Singapore	0.6	1.0	0.0	7.3	0.5	0.1	0.1	0.1	1.3	1.8	12.5	25.3
Thailand	0.0	0.2	0.0	0.1	35.7	0.2	0.1	0.1	0.8	1.3	8.6	47.2
China	1.7	2.0	1.5	4.1	1.8	1,403.0	0.2	0.3	27.0	23.6	104.0	1,569.2
Taiwan	0.4	0.3	0.1	0.4	0.3	1.2	42.3	0.4	3.1	17.2	14.0	79.6
Korea	0.4	0.3	0.2	0.3	0.2	0.1	0.2	78.2	4.5	13.0	24.8	122.1
Japan	2.7	1.6	0.3	1.7	2.0	14.1	2.7	4.9	810.9	55.6	85.9	982.5
USA	2.5	2.2	0.9	2.3	1.2	7.5	4.2	6.7	30.6	4,427.6	332.3	4,818.0
Total	73.3	28.2	26.4	17.9	42.1	1,426.9	50.0	91.3	884.0	4,548.9	597.7	7,786.8

Table 7 Embodied CO2 Transactions in 2000 (unit: million ton)

	In	Ma	Ph	Si	Th	Ch	Ta	Ko	JPN	USA	ROW	Total
Indonesia	184.1	2.3	1.2	2.1	2.0	5.0	2.8	3.9	15.9	19.4	52.9	291.6
Malaysia	1.1	46.8	1.1	4.6	1.8	4.5	2.3	2.1	11.4	22.5	48.0	146.2
Philippines	0.1	0.3	49.1	0.2	0.3	0.8	0.5	0.5	3.4	8.0	12.9	76.0
Singapore	0.5	1.8	1.1	19.7	1.0	2.5	1.2	0.9	2.4	5.1	35.0	71.2
Thailand	0.7	1.2	0.5	1.2	103.7	2.5	1.2	0.9	7.8	12.6	42.0	174.3
China	4.6	4.8	1.9	5.3	6.2	2,466.4	9.9	19.5	104.3	198.5	399.4	3,220.8
Taiwan	0.8	1.1	0.6	0.6	1.3	14.2	143.0	1.5	8.3	20.1	56.2	247.7
Korea	1.9	1.2	1.3	1.0	1.3	19.5	4.0	356.2	18.3	28.7	103.3	536.8
Japan	1.3	2.1	0.8	1.9	2.4	8.4	5.1	4.9	919.1	34.1	70.4	1,050.6
USA	1.9	2.8	1.6	2.9	3.0	13.1	10.4	12.0	43.0	5,448.3	518.5	6,057.5
Total	197.1	64.5	59.2	39.5	122.9	2,537.0	180.3	402.6	1,133.8	5,797.2	1,338.7	11,872.8

3-3 Embodied land transaction

Table8 and Table 9 show the embodied land transaction in 1985 and 2000, respectively. As referring in section 2, land use here is limited only for agriculture and livestock industry.

Taking a look at total amount of land used directly and indirectly (the extreme right column), it is found that China and the United States are prominently large; 496

million hectare is in China and 431 million hectare is in the United States in 1985. Japan, Korea, Thailand and China are listed as the countries which use land of the United States indirectly, while Japan, the United States and Korea use land of China indirectly. As far as Japan is concerned, total amount of Japan's land usage was around 32.7 million hectare, and only 5.7 million hectare was used domestically in 1985. This means that 82.6% of land used by Japan was in foreign countries in 1985. While its ratio rises a little in 2000, it is notable that Japan's land usage in China has drastically increased.

Table 8 Embodied Land Transaction in 1985 (unit: 1000 ha)

	In	Ma	Ph	Si	Th	Ch	Ta	Ko	JPN	USA	ROW	Total
Indonesia	35,876	44	20	43	15	134	35	71	631	995	1,814	39,679
Malaysia	24	3,758	18	112	23	75	46	209	859	322	518	5,963
Philippines	2	7	9,610	9	4	24	13	22	440	415	363	10,910
Singapore	0	0	0	3	0	0	0	0	0	1	1	5
Thailand	36	558	11	133	14,675	221	98	213	856	937	2,840	20,577
China	765	487	165	484	238	456,375	22	36	9,077	3,522	24,726	495,897
Taiwan	8	33	9	36	5	7	7,127	41	900	368	343	8,877
Korea	0	1	2	1	0	0	1	2,030	76	34	73	2,220
Japan	2	2	3	2	2	9	5	6	5,694	78	76	5,879
USA	434	182	134	152	191	1,815	1,929	2,270	14,154	365,846	44,289	431,399
Total	37,147	5,072	9,973	974	15,154	458,661	9,277	4,899	32,687	372,519	75,042	1,021,405

Table 9 Embodied Land Transaction in 2000 (unit: 1000 ha)

	In	Ma	Ph	Si	Th	Ch	Ta	Ko	JPN	USA	ROW	Total
Indonesia	37,209	198	55	107	105	389	167	212	1,348	1,684	3,302	44,777
Malaysia	62	3,426	48	342	66	285	132	124	756	571	2,078	7,890
Philippines	10	11	10,695	7	8	58	15	71	510	335	431	12,150
Singapore	0	0	0	1	0	0	0	0	0	0	0	1
Thailand	160	215	51	89	12,390	202	197	137	1,312	1,345	3,947	20,045
China	692	643	245	369	459	495,997	437	2,900	13,525	9,054	24,337	548,658
Taiwan	5	12	5	9	14	49	7,712	20	291	127	272	8,515
Korea	1	1	1	1	1	9	3	1,812	64	17	63	1,973
Japan	1	2	1	2	2	7	6	8	5,137	29	64	5,258
USA	621	236	397	170	532	2,278	2,964	2,243	15,811	345,063	44,084	414,398
Total	38,761	4,743	11,498	1,095	13,576	499,275	11,632	7,527	38,753	358,226	78,578	1,063,665

3-4 Embodied water transaction

Table 10 shows the embodied water transaction in 2000. As well as the case for land, water use here is limited only for agriculture and livestock industry.

Taking a look at total amount of water used directly and indirectly (the extreme right column), it is found that water usage in China is extremely large, i.e. 426.8 billion ton. Focusing on transaction inter-regionally, Japan's water usage in China is the most (10.5 billion ton). Though Japan uses around 81.9 billion ton water directly and indirectly, the ratio of water used domestically accounts for just 66%, which is the lowest value except for Singapore and Malaysia.

Table 10 Embodied Water Transaction in 2000 (unit: billion ton)

	In	Ma	Ph	Si	Th	Ch	Ta	Ko	JPN	USA	ROW	Total
Indonesia	62.8	0.3	0.1	0.2	0.2	0.7	0.3	0.4	2.3	2.8	5.6	75.6
Malaysia	0.0	2.4	0.0	0.2	0.0	0.2	0.1	0.1	0.5	0.4	1.5	5.6
Philippines	0.0	0.0	18.6	0.0	0.0	0.1	0.0	0.1	0.9	0.6	0.7	21.1
Singapore	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Thailand	0.7	0.9	0.2	0.4	51.1	0.8	0.8	0.6	5.4	5.6	16.3	82.7
China	0.5	0.5	0.2	0.3	0.4	385.9	0.3	2.3	10.5	7.0	18.9	426.8
Taiwan	0.0	0.0	0.0	0.0	0.0	0.1	11.8	0.0	0.4	0.2	0.4	13.0
Korea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.2	0.3	0.1	0.3	8.9
Japan	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	54.0	0.3	0.7	55.2
USA	0.3	0.1	0.2	0.1	0.3	1.1	1.4	1.1	7.5	164.7	21.0	197.7
Total	64.4	4.3	19.3	1.2	52.0	389.0	14.8	12.8	81.9	181.7	65.4	886.8

4. Concluding Remarks

The research estimated, in the previous section, "embodied environmental load" in the Asia-Pacific region applying input-output analysis. The main finding is as follows.

First, the United States, China and Japan rank top 3 as to the total amount of energy consumption and CO2 emissions in the Asia-Pacific region. It is especially notable that China's increase is prominently large during 15 years between 1985 and 2000. In 1985, the United States and Japan are "factory place" of goods (exporting countries) as well as the consuming places (importing countries). In other words, they not only carried CO2 emissions in place of other countries but also they made other countries to carry their own CO2 emission load. However, it is found that in 2000 the role as consuming place of goods (country to use other countries' energy) was prominent in Japan and the USA. On the other, China has changed from the importing country of goods to exporting country, and its role to carry CO2 emission load in place of other countries has been strengthened.

Furthermore, we also estimated the amount of indirect use of land and water for

agriculture. The ratio of Japan's land usage outside the country has been extremely high, and particularly Japan's indirect land use in China has drastically increased. As for water consumption, the situation for Japan is similar to the case of land usage. Japan uses relatively much water in other countries and most of indirectly imported water is from China.

Statistics

1 International Input-Output tables

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2 Energy consumption

1985 : IEA, World energy statistics and Balances, 1985-1988

2000 : IEA, Energy balances of OECD countries, 1999-2000 and

IEA, Energy balances of Non-OECD countries, 1999-2000

3 CO2 emission coefficient

Source: The Institute of Energy Economics, Japan, *2008 EDMC Handbook of Energy & Economic Statistics in Japan*

4 Land and water consumption

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