Effect of Hot Summer against Environment which was induced by Extra Economical Demand via Japanese Ecological Footprint

K. Yamasaki, T. Fujiwara, N. Sakurai, K. Yoshizawa, Z. Zheng

Tokyo University of Information Sciences, 4-1 Onaridai, Wakaba-ku, Chiba,Japan
(Tel&Fax : 81-43-236-4653)
(yamasaki@rsch.tuis.ac.jp)

Abstract: The Ecological Footprint (**EF**) indictor which had been presented by Wackernagel and Rees in 1990's has attracted larger attention as a numerical assessment value for sustainable development on Earth. In this paper, we analyze the effect of hot summer against environment which was induced by extra demand via Japanese **EF** based on 47 prefecture's Input-Output table. The electricity sector and the gas & heat supply sector are affected by high temperature within 48 industry sectors in this Input-Output table. The extra demand of the electricity sector increases in the **EF** through the increase of CO2 emission in the same prefecture and the same sector. The effect of the extra demand loss of the gas & heat supply sector is not strong but is affected opposite direction. The extra demand(demand loss) does not affect other prefectures and other sectors so much.

Keywords: Ecological Footprint, Input-Output table, Induced analysis,

I. INTRODUCTION

We have to pay some money to buy food , clothes and electricity etc. for daily life. Although, the air for breathing is free and we live without being aware of the environmental services such as "regulation of CO2/O2 balance", "greenhouse gas regulation" and "flood control". R. Costanza and his team calculated the main 17 ecosystem services we received in 1997. These values (most of which is outside the market) is estimated US$33 trillion per year and it's comparable to global world economy of US$38 trillion per year on purchasing price basis. For sustainable life market price is not enough as the metric and we need more effective numerical value. One of the candidate is **EF**. The essential part is to convert nation's basic consumption to the nation's virtual area which is necessary to produce it. For example, we consume agricultural products to keep our life, and the consumption is converted to cropland area, and finally our total consumption is compared to bio capacity of the globe.

II. INDUCED ANALYSIS OF EF

EF is represented by total area of six land types, "Cropland", "Forest", "Grazing land", "Fishing ground" , "Carbon uptake land" and "Built-up land". Each area is calculated to reproduce our final consumption as necessity area for "the supplies of crop", "the supplies of wood", "the supplies of livestock feed" , "the supplies of fish", "absorption of CO2 emission" and "house, factory, road etc.". And it is compared to the real area (bio capacity) on the globe. Actually Japan needs 2.5 times area of Japan to keep our lifestyle, and whole world people need more area than whole area of the globe.

EF is calculated for an area on the basis of consumption in the area. That is **EF** of the imported product does not belong to the nation where the product is produced but belongs to the nation where the product is consumed.

$$EF = \sum \frac{1}{y_{N,\alpha}} \varepsilon_{l(\alpha} \psi_{N\,l,\alpha(} \chi_{\gamma i} \chi_{ij} \cdots \chi_{k\Omega} C_{\Omega} \quad (1)$$

Here C_{Ω} is the weight of the consumed product Ω of which we want to know the effect, χ_{ij} is the weight of the product i to produce unit weight of product j, $\varepsilon_{l(\alpha)}$ is the equivalence factor of land type $l(\alpha)$ for the product α *, $\psi_{N,l(\alpha)}$ is yield factor of nation N and land type $l(\alpha)$, $y_{N,\alpha}$ is the average weight of the product from unit area in the nation N. And the sums are executed in all paths from product Ω to product α through intermediate products *i, j*... Using the matrix representation, $\{1+\chi+\chi\chi+\chi\chi\chi+\quad\} = [1-\chi]^{-1}$, and

$$\mathbf{EF} = \boldsymbol{\lambda}[\mathbf{1}-\boldsymbol{\chi}]^{-1}C \quad (2)$$

here $\boldsymbol{\lambda}$ is diagonal matrix of $\varepsilon_{l(\alpha)}\psi_{N,l(\alpha)} / y_{N,\alpha}$.
But usually it is difficult to know χ_{ij} of all products' pairs [*i, j*] without double counting. Sometimes we want to measure the effect of consumption toward other sectors or toward other regions, not only on economic effect but also on environmental effect. Input-Output table enables to calculate such influences by induced analysis.

*The equivalence factors and the yield factors are defined by GFN and represent the differences of productivity between different land types and between different nations.

$$\mathbf{EF} = \boldsymbol{\lambda}[\mathbf{1}-\boldsymbol{\chi}]^{-1}C + \boldsymbol{\lambda}^{fuel}C \qquad (3)$$

In eq.(3), C is a demand vector of sectors expressed by amount of money, χ is the coefficient matrix and $[\mathbf{1}-\boldsymbol{\chi}]^{-1}$ is the Leontief Inverse Matrix of the Input-Output table. λ is a kind of induced value added matrix in Input-Output table analysis.
Additional term $\boldsymbol{\lambda}^{fuel}C$ represents CO2 emission from the direct fuel use of final consumption.
For example, in case of agriculture sector, $y_{N,\alpha}$ is the total amount of agricultural product divided by the total area of the Cropland of the considering region N. $\varepsilon_{l(\alpha)}$ is the equivalence factor of Cropland, $\psi_{N,l(\alpha)}$ is yield factor of the region N and Cropland **.

There is another method to calculate the matrix λ.
GFN calculates nation's EF_l of each land type l every year and these EF_ls represent the area after considering the productivity. If EF_ls were distributed to each sector α(They are called direct **EF**s), λ is able to replace by them. The merit of this method is induced **EF**s are able to compare to other nations' **EF**s through **EF**s calculated by GFN.

III. THE EFFECT OF HOT SUMMER

1. We use "Multi-regional Input-Output table for 47 Prefectures and 48 industry sectors in Japan" in 2000 [1]. First we transform this Chenery-Moses type Input-Output tables of 47 prefectures to a Isard type table[2], which includes 2256x2256 matrix.

Table 1. a part of the Isard type Input-Output table.

		1	2	3	4	5
	million Yen	Hokkaidou_ Agriculture	Hokkaidou _Forestry	Hokkaidou _Fishery	Hokkaidou _Mining	Hokkaidou _Food_Drink
1	Hokkaidou_ Agriculture	607	30	82	61	1546
2	Hokkaidou_ Forestry	111	5	15	11	281
3	Hokkaidou_ Fishery	132	6	18	13	335
4	Hokkaidou_ Mining	50	2	7	5	127
5	Hokkaidou_ Food_Drink	1019	50	138	103	2594
27	Hokkaidou_ Electricity	264	13	36	27	671
28	Hokkaidou_ Gass	29	1	4	3	74

2. Next we allocate the **EF** calculated by GFN to each sector of each prefecture. **EF**s are allocated in proportion to the total of each sector according to the Table 2. We divide **EF** of Carbon uptake land into two parts in proportion to the total, one is for intermediate industry and the other is for final consumption. Using 3EID table[3], we allocate Carbon uptake land **EF** of intermediate industry in proportion to the total (million yen) of each sector multiplied by CO2 emission unit requirement(t-CO2/million yen).

Table 2. Land types and corresponding sectors

1	EF of Cropland	Agriculture sectors
2	EF of Forest	Forestry sectors
3	EF of Grazing land	Agriculture sectors
4	EF of Fishing ground	Fishery sectors
5	EF of Carbon uptake land	All sectors Final consumption
6	EF of Built-up land	All sectors

3. We use "Monthly Family Budget Survey" calculated by Japanese government[4] to get the extra consumption for the hot summer. We calculate the correlation between temperature and consumption of each 48 sector in July in main cities in Japan. We found that the electricity consumption of 11 years has positive correlation to the temperatures, and that the gas & heat supply consumption has negative correlation.

4. We calculate induced demand using eq.(4) and calculate induced **EF** using eq.(5). The elements of C are the extra consumption of the electricity sector and the extra loss consumption of the gas & heat supply sector. We calculate the data of the hot summer in July/2010. We also calculate the data of the cold summer July/2003 for comparison. When we use the competitive import type Input-Output table, eq.(3) must be deformed to eq.(5) for separating imported products from domestic products.

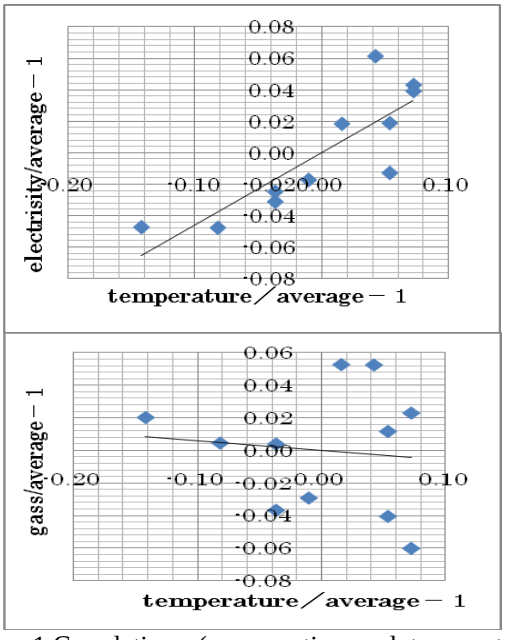

Figure.1.Correlations (consumption and temperature)

**If the region is not a nation, we use $\psi_{N,l(\alpha)}$ of the nation's factor instead.

$$\mathbf{W} = [\mathbf{1} - [\mathbf{1} - \mathbf{M}]\chi]^{-1}[\mathbf{1} - \mathbf{M}]C \quad (4)$$

$$\mathbf{EF} = \lambda[\mathbf{1} - [\mathbf{1} - \mathbf{M}]\chi]^{-1}[\mathbf{1} - \mathbf{M}]C + \lambda^{fuel}C \quad (5)$$

Here **M** is import ratio diagonal matrix whose elements indicate the ratio of imported products in total products.

5. The last term of eq.(5) represents CO2 emission from the direct fuel use of final consumption. Using 3EID table, we calculate the remaining CO2 emission ratios (t-CO2/million yen) in energy sectors and Carbon uptake land **EF** of final consumption is allocated in proportion to the total multiplied by these ratios.

IV. RESULT

Figure.2 shows the effect from extra demand of electricity/gas respectively in 47 prefectures in 2010. Three lines show extra household consumption, induced production and the extra use of the "Carbon uptake land". In July 2010, The hot summer already began in the east part of Japan, but the heavy rainy season still stayed in the west part of Japan. So high demand of electricity is clear in east part of Japan. The high demand does not affect other prefectures' production so much except Fukushima where there is nuclear plant of Tokyo Electric Power Company. The effect from gas consumption is not so clear. Figure.3 shows the effect from extra demand of electricity/gas respectively in 48 sectors. The electricity consumption induces the production of Coke & Petroleum, Finance & insurance and Other business services. But it looks as if production of the electricity does not induce the increase of CO2 emission in other sectors, because the production of the electricity produces carbon dioxide in higher ratio per money than other sectors.
Figure. 4 (Figure. 5) shows the effect from extra(loss) demand of electricity/gas in 47 prefectures(in 48 industry sectors) respectively in cold summer in 2003. The results are almost opposite to the hot summer in 2010.

V. DISCUSSION

The extra demand(demand loss) does not affect other prefectures and other sectors so much. It comes from characteristic of these industries. But the true effect of the hot summer is thought to have spread widely in various industry sectors. Input-output table of 47 prefecture includes only 48 sectors and there is no Input-output table with much sectors in all prefectures level. we have to give up the analysis of the prefectures level and use Input-output table with more sectors to improve the study.

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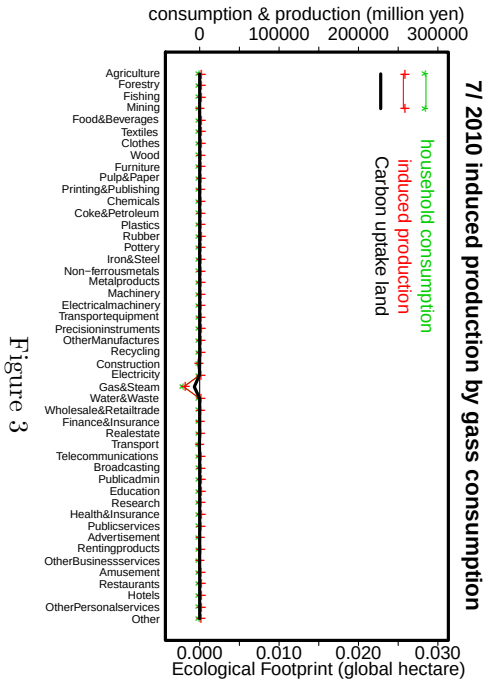


Figure 3

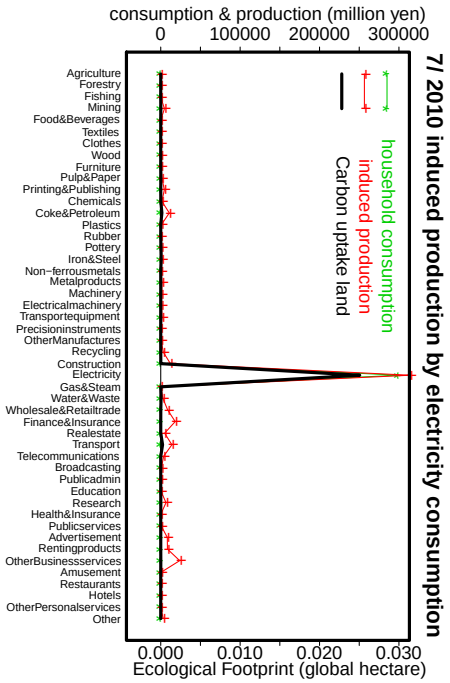


Figure 2

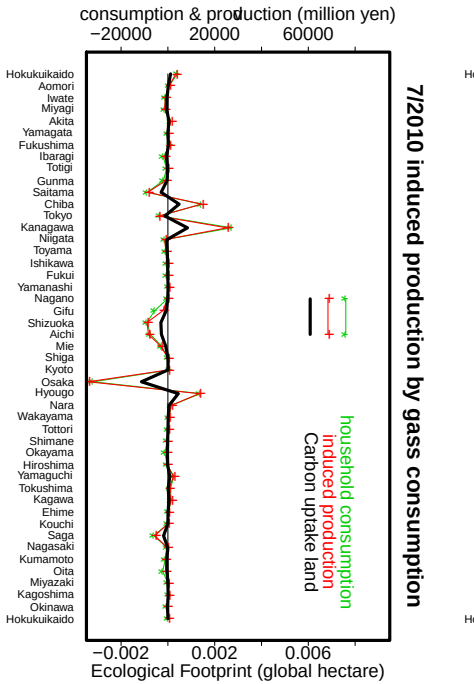
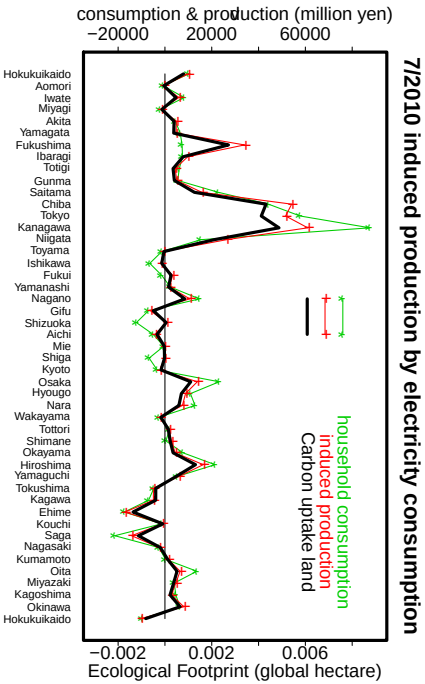


Figure 4



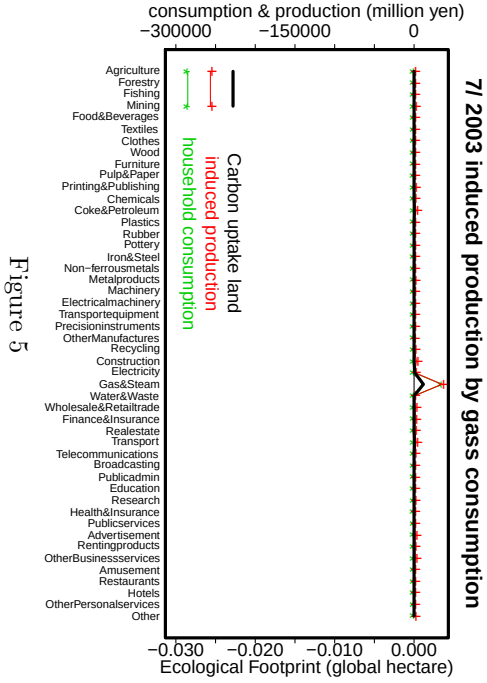


Figure 5