A GENERAL EQUILIBRIUM ANALYSIS OF THE WASTE-ECONOMIC SYSTEM - A CGE-MODELING APPROACH -*

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1. Introduction

It has recently been a very important issue to examine the interaction between environment and economic activities. Appart from specific researches on environment relating to industrial activities, inhabitants, or transportation, however, empirical studies on a national or regional macro-environment/economic system have stayed at initial stages, resulting in the insufficiency of systematizing the environment/economic interaction. The main reason of this matter may be attributed to a significant complexity of environment/economic system, and a need for tremendous works to collect and arrange data on the system. Considering these matters, this article focuses on waste in Hokkaido, Japan, as an environmental pollution factor, then construct a computable general equilibrium (CGE) model[1),2)] in order to analyze the interaction between environment and the economy of Hokkaido. Our analysis aims to evaluate the effects of charging household waste discharge, technical progress in waste clearing activities, and promotion of recycling etc. on Hokkaido's economy.

2. The Model

(1)Assumption of the model

The model is linked to the following assumptions.

① Economic agents in the model are; aggregate household, industries (primary, secondary and tertiary), the government, industrial waste self-clearing activities (primary, secondary and tertiary), contract/public clearing activity, and the external sector. Hereafter, the waste clearing activities are, in short, denoted by S-activity and C/P-activity, respectively.

② There are nine markets including three commodity, four waste clearing and two factor (labor and capital) markets.

③ Commodity and factor markets are perfectly competitive and the real economic world is in long run equilibrium.

④ The benchmark year is 1985.

(2)Structure of the model

① Industries

Industries employ intermediate goods, labor and capital with minimum costs, and discharge industrial waste while produce commodities. Almost of waste is cleared by the S-activities, but a part of waste is disposed of by the C/P-activity. These clearing services are inputted to industries like intermediate goods. Labor and capital incomes yielded in production processes are distributed to households.

The technology of industries is divided into two parts. Leontief technology is adopted to inputs of intermediate goods, value added, and waste clearing services. Cobb-Douglas technology is employed in producing value added with labor and capital

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inputs.

②Households

Households discharge general waste while consume commodities. Households have CES utility function of leisure and waste/commodity composite good. Households demand leisure and waste/commodity composite good in order to maximize their utility under the income that is obtained by supplying the entire labor force and capital which they hold. The income is called "full income". Waste/commodity composite good is then divided into general composite good and waste through maximizing a subutility function with given prices and waste charges. Waste charges paid by households constitue a part of government revenues. General composite good is further divided into commodities produced by industries through maximization of Cobb-Douglas utility function.

Households must pay direct taxes, and are assumed to save a part of income with an exogenous marginal saving ratio. Household savings are used for capital investment.

③Waste self-clearing activities

Almost of industrial waste is cleared by the S-activities with constant clearing ratios. The S-activities dispose of industrial waste, like industries, employing inputs of intermediate commodities, labor and capital under the cost minimization principle. The technologies of S-activities are Leontief type with respect to inputs of intermediate commodities and value added, and Cobb-Douglas type in production of value added, respectively.

④Contract/Public waste clearing activity

The C/P-activity disposes of a part of industrial waste and entire household waste. The C/P-activity behaves also under the cost minimization principle. Services produced by the C/P-activity are purchased by the government and industries. The technologies of C/P-activity are assumed to be the same as those of the S-activities.

⑤The government

The government obtains its income from net indirect taxes paid by industries, direct taxes on households, household waste charges, and current transfers from the external sector. Then the government disposes of the income as government consumption expenditures, expenditures on the C/P-activity, current transfers to households, and currenet transfers to the external sector. The difference between income and expenditures is assumed to be saved, and used for capital investment.

⑥The external sector

The external sector consists of other Japan than Hokkaido and foreign countries. The external sector gains its income from Hokkaido's imports and factor income/other current transfers from Hokkaido, expending the income on Hokkaido's exports and factor income/other current transfers to Hokkaido. The gap between income and expenditures is assumed to be saved composing a part of Hokkaido's domestic capital investment.

⑦Market equilibrium

As mentioned earlier, there are nine markets in the model including three commodity, four waste clearing, and two factor markets. The CGE-modeling aims at finding the equlibrium prices that clear all the markets. In the model, however, the zero profit condition on industries and waste clearing activities, the budget balance constraint on households, the government and the externl sector, and intestment/savings balance lead to the Walrasian law. Moreover, supplies of industries and waste clearing activities are determined by market demands because of the linear homogeneity in the technologies of them. These conditions, therefore, result in the fact that the labor or capital market is only an independent market. In the model, we regard capital as numerare, and compute the equilibrium wage rate in labor market by applying the Newton-Raphson method.

3. Simulation Analysis

Numerical experiments of nine cases are done in the study. The simulation cases are presented in Table 1 while simulation results of some key variables are illustrated in Table 2. In Table 2, figures in Standard Case (=the benchmark year data) are presented as real values while those in other cases are depicted as variation ratio to Standard Case. The simulation results are briefly summarized in a subsequent context, however, explanations for Cases 3 to 6 are skipped because of the page constraint.

(1)Cases 1 and 2

The results of Case 1 show that discharge of household waste significantly decrease by 25% of that in Standard Case, because of charging the household waste discharge. The charges directly reduce the amount of household consumption, however, decrease the demand for the C/P-activity as well. The decrease in the demand leads to a shift of labor and capital to industries, resulting in a slight increase in household income. The leisure demand increases but a decrease in household consumption results in a reduction in household utility, that is, EV shows -8.6 billion yen.

Case 2 examines the effects of a taxation of the sum of direct taxes and waste charges in Case 1 on households. The taxation does not significantly affects household waste dischrge as a slight decrease by 0.06%. Also the taxation more moderately depresses household consumption expenditures than in Case 1. The government gains more revenues, resulting in an increase in industrial outputs derived by an expansion of government consumption expenditures. Gross prefectural products, however, show a decrease. The decrease in household consumption derived by the taxation more affects the household utility than an increase in the household leisure demand, resulting in a negative EV of 5.1 billion yen.

As mentioned above, it can be concluded that charging household waste dischage is more effective than direct taxation from the viewpoint of reduction in waste discharge, but less effective from a welfare point of view.

(2)Cases 7, 8, and 9

In Case 7, free recycling activities are introduced to industries. This implies a technical change with an economy in intermediate inputs. A decrease in intermediate inputs from the secondary industry reduces the size of secondary industry, but grows the value added resulting in an expansion of household income and consumption. The increase in household income leads to a positive EV of 8.6 billion yen despite a decrease in household leisure demand. The total waste dischage is less than that in Standard Case since the reduction in industrial waste exceeds the increase in household waste.

In Case 8, it is assumed that recycled goods are supplied by the tertiary industry. Thus second industry products are substituted by tertiary goods resulting in a decrease in the secondary industry. Commodity prices get lower, and household consumption grows. But an expansion in labor demand of the tertiary industry decreases more household utility than in Case 7 since EV shows 1.5 billion yen. The total waste is also reduced.

Case 9 assumes a free recycling by households. The recycling reduces household consumption of virgin products leading to decreases in industries. Commodity prices significantly fall as compared to ohter cases. The depression in the economy, as a natural consequence, much reduces waste. However, EV is largely raised by 30 billion yen since a preference change is assumed in the case.

4. Concluding Remarks

The study has constructed a CGE-model including an interaction of the economy and waste discharging/clearing, then carried out some numerical simulations. The study can be evaluated as a rare approach in Environmental Economics, however, there may be some points that should be improved. Above all, a more detailed classification of industries is pointed out. Such a classification leads to a more detailed examination of the waste/economic interaction.

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Table 1. Simulation Cases

Cases	Contents
S.Case	Values of the benchmark year data.
Case 1	Household waste discharge is charged at a rate of 40yen per 10kg.
Case 2	Direct taxes which are the same to the sum of waste charges and direct taxes in Case 1 are imposed on households.
Case 3	The ratios of industrial waste to outputs are decreased by 10% in industries, respectively.
Case 4	The ratio of household waste to consumption is decreased by 10%.
Case 5	Operating costs in the S-activities are reduced by 10%.
Case 6	Operating costs in the C-activity are reduced by 10%.
Case 7	A free recycling which lowers inputs from the secondary industry by 10% is intoduced to industries.
Case 8	A recycling which cut down 10% of inputs from the secondary industy is introduced to industries. The recycled goods are assumed to be supplied by the tertiary industry.
Case 9	A free recycling which reduces household consumption of virgin commodities by 10% is introduced to households.

Table 2. Simulation Results of Key Variables (in variation ratio to Standard Case)
(unit: in %. Household waste charges and EV are in million yen.)

variables	Real values in S. Case	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
industrial outputs	22,932,737	0.060	-0.015	-0.945	-0.851	-0.958	-0.837	-3.613	-1.265	-6.723
outputs of waste clearing act.	202,982	-3.643	-0.020	-8.512	-1.409	-6.924	-2.995	-6.853	-5.830	-7.334
household income	14,642,893	0.021	0.012	0.001	0.003	-0.002	0.005	-0.049	-0.106	-5.183
household consumption	9,625,270	-0.078	-0.070	0.000	0.003	-0.002	0.005	-0.050	-0.107	-6.120
labor demand	7,407,223	-0.027	-0.016	-0.017	-0.005	-0.012	-0.010	0.076	0.184	-6.267
government income	7,079,202	0.148	0.142	0.006	0.003	0.003	0.006	0.010	-0.188	-2.681
capital investment	4,251,462	0.278	0.040	-0.060	0.076	-0.100	0.117	-0.188	-0.221	-5.269
waste discharged	35,371,908	-2.268	-0.010	-8.984	-0.880	0.084	0.063	-4.748	-3.858	-3.956
primary industry	13,112,662	0.087	-0.005	-9.897	0.031	0.084	0.062	-4.559	-4.004	-3.026
secondary industry	15,394,144	0.133	-0.002	-9.882	0.044	0.086	0.089	-6.838	-6.182	-5.028
tertiary industry	3,643,357	-0.014	-0.012	-9.964	0.002	0.036	0.007	-0.915	2.966	-3.245
households	3,221,745	-25.876	-0.063	0.131	-10.003	0.123	0.005	0.135	0.126	-3.425
price of primary good	1.0000000	0.018	-0.012	-0.093	0.011	-0.098	0.015	-0.286	-0.363	-4.673
price of secondary good	1.0000000	0.012	-0.007	-0.262	0.007	-0.236	-0.019	-0.238	-0.289	-2.987
price of tertiary good	1.0000000	0.010	-0.006	-0.079	0.006	-0.082	0.008	-0.161	-0.207	-2.656
rate of capital returns	1.0000000	0.026	-0.016	-0.053	0.015	-0.069	0.031	-0.385	-0.499	-6.587
price of consumption good	1.9895589	0.011	-0.007	-0.131	0.006	-0.125	0.001	-0.185	-0.233	-2.791
price of prim. S-act. service	108	0.013	-0.008	-0.078	0.007	-10.071	0.008	-0.199	-0.255	-3.225
price of sec. S-act. service	9,167	0.014	-0.009	-0.084	0.008	-10.078	0.011	-0.224	-0.287	-3.664
price of ter. S-act. service	8,905	0.014	-0.009	-0.071	0.008	-10.067	0.012	-0.221	-0.283	-3.647
price of C/P-act. service	9,112	0.006	-0.004	-0.045	0.004	-0.045	-9.997	-0.103	-0.131	-1.657
household waste charges	0	9,552	0	0	0	0	0	0	0	0
equivalent variation	0	-8,558	-5,140	13,607	-71	12,496	1,037	8,624	1,547	29,888

Note1: Labor demand in Standard Case is denoted in a quantity which yields services of one million yen.
Note2: In Standard Case, waste discharge is in ton, prices of waste clearing services are in million yen/ton, and others are in million yen.
Note3: Variation ratios are in nominal term except labor demand and waste discharge.

References

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