IR-1.3 Development of environmental and resources flow accounts based on the input-output model

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Abstract

This study aims at the development of the framework for physical accounts to describe the flows of natural resources and environmental burdens between the nature and the economy and those among sectors of the economy. A framework of multi-dimensional physical input-output tables (MDPIOT) with environmental extension was proposed and preliminary accounts for fossil fuels, construction materials and iron & steel were compiled. The GAMEE, an extended, flexible and consistent framework containing both physical and monetary account, was also proposed. Energy consumption and CO_2 emissions database along with the 1995 I-O table data was compiled and recent structural changes were analyzed. Collection of data and calculation of indicators for total material outflows from the economy to the nature were undertaken as a second phase of the collaborative study with Austria, Germany, the Netherlands and the United States. Case studies on local material flows and specific commodity flows were also undertaken.

Key Words Environmental Accounting, Physical Accounting, Input-Output Tables, Material Flow, Resources

1. Introduction

The development of environmental accounting and its use for indicators of sustainable development is recognized to be urgent and important research subjects, since the chapter 8 of the Agenda 21 referred to the needs for the environmental and natural resource accounts, and the integrated System of Environmental and Economic Accounting (SEEA) was introduced within the 1993 revision of the System of National Accounts (SNA). Studies on such an integrated accounting system and the interaction between the economy and the environment are included as one of the key research areas in the Basic Environment Plan of Japan.

To respond to such domestic and international research needs, we developed the framework of physical Material Flow Accounting (MFA) and compiled macroscopic accounts of major resource flows. However, further studies are needed to develop more detailed physical accounts based on the input-output model, in order to apply the results of accounting studies to policy analysis by economic-environmental modeling.

2. Research Objective

Based on such research needs and the stock of past studies, this study aims at the development and improvement of the framework for physical accounts to describe not only the flows of natural resources and environmental burdens between the nature and the economy but also those among disaggregated sectors of the economy. By re-organizing the results from existing studies on inter-sectoral and inter-regional material flows into the framework of input-output tables, we intend to compile physical material flow accounts, which can be used as an inputs to various analysis and modeling, e.g., a structural decomposition analysis of resource use and waste generation. In order to show the usefulness of physical material flow accounts, an international comparison study of macro indicators of material flows and several case studies on accounts for specific material categories and those at local scale will also be undertaken.

3. Research Method, Result and Discussion

(1) Design of the framework for physical input-output accounting

Recently, MFA studies attract renowned interests under the field of environmental accounting mainly by statisticians and economic accountants. An origin of conceptual framework of the MFA can be found in the material balance approach in the field of environmental economics and extension of economic Input-Output analysis (IOA). So-called 'Energy Analysis' was a typical field of application since early 1970s. More recent studies in the field of inventory analysis for Life Cycle Assessment (LCA) have large similarities with these past studies. In addition, application of IOA to the issues of waste management and recycling is getting active.

Based on the review of these studies on environmental extension of I-O analysis, description of whole physical material flows within the economy and their interaction with the environment was attempted using I-O framework. Learning from the German pioneering experiences in PIOT (Physical Input-Output Tables), this study proposed a preliminary framework of MDPIOT (Multi-Dimensional PIOT. The proposed framework is presented in Table 1. As shown, MDPIOT consists of multi-layered matrices, of which each layer describes physical flows of a specific category of materials among economic sectors including waste recovery and recycling sectors, as well as flows between the economy and the environment. At the first stage, data gatherings and preliminary tabulation for fossil fuels, construction materials and iron & steel were attempted.

This framework has several remarkable merits. Above all, this can link sectoral Input-Output studies with nation-wide bulk MFA studies. In addition, the material input-output balance (mass conservation) of each sector can be explicitly ensured, by accounting

Table 1 An overview of the framework for multi-dimensional physical input-output tables

Resource total

Sheets for resource type as 3rd dimension

Resource C

Resource B

Resource A

Supply(input) \ Use (output)			Production				Consumption, accumulation			Rest of the world		Environment		Other resources
			Base material	Manufacturing	Service	Waste management	Consumption	Capital formation	Waste storage	Export	Import	Env. as source	Env. as sink	
Level1	Level2	No.	1	2	3	4	5	6	7	8	9	10	11	12
Production	Base material	1	(-,+)*	Flow of intermediate products (+)		Interm. inputs for waste manag.	Material flows to final demand sectors (+)			(+)	(-)			
	Manufacturing	2	Flow of intermediate products(+)	(-,+)*										
	Service	3			(-,+)*									
	Waste management	4	Material flow other than wastes accompanied by waste management activities (+)											
Recovery	Recovered material	5	Recovery of by-products(-) and outputs to recycle/treatment/disposal(+)				Recovery of materials (-)		(-)					
Accumulation	Intermediate product	6	Apparent intermediate flow				Stock (+)							
	Waste storage	7				Final disposal(-)			Stock (+)					
Environment	Env. as source	8	Resource extraction, oxygen input for combustion , etc (+)									Extraction total (-)		
	Env. as sink	9	Direct emission of substances (CO2, etc.) from economic activities to the environment					Erosion (-,+)					Emission total (+)	
Internal transformation		10	Internal transformation across type of resources											Balance (+,-)

*) For diagonal elements in production activities, gross production should be indicated with negative sign and self-consumption should be indicated with positive sign.

not only for valued inflows (raw materials) and outflows (products) but also for valueless inflows (e.g. oxygen for combustion) and by-products. Wastes stream can also be captured and described more systematically. It can also describe relation between flows and stock changes, such as accumulation of materials for infrastructures and durable products within the economy. Up to now, the framework is applied to a single nation with simple description of import and export. However, this should be extended to describe international trade flows more explicitly and more in detail, so as to respond to policy-relevant questions.

In order to support the data handling within this framework, the "pivot table" function of the "Microsoft® Excel" was exploited. By using this function, the operation for aggregation and disaggregation of sectors is realized in quite easy and flexible manner, i.e., by just clicking the target cells. Different type of accounting matrices can be displayed by allotting supply sectors, use sectors, and commodities to rows and columns of spreadsheets. Once figures are filled in the framework, MDPIOT can provide us with information basis not only for aggregated indicators but also for sector-specific and material-specific indicators. Moreover, MDPIOT will be useful for the analysis of structural changes of the relation between economic growth and resource/waste flows.

(2) Study on air emissions from fossil fuels based on 1995 I-O tables

As stated above, IOA has been applied for the energy analysis late 1970s. Similar methodology can be applied to analyze direct and indirect emission of CO_2 and other burdens to the atmosphere induced by various economic activities, using emission factors and energy consumption data. Energy consumption by economic sectors is reported in physical unit tables, which is officially accompanied with national IO tables. Other official statistics on energy consumption are used in order to supplement the data in physical unit tables, of which data coverage and accuracy are not complete. This calculation process had been applied to the compilation of CO_2 emission database for 1975-1990 by past studies. During the period of this study, 1995 I-O tables were made available. Using this most recent tables and by applying improved estimation method for sectoral fuel consumption, emissions of CO_2, NOx and SOx were newly calculated for the year 1995, and 1990 data were revised. Using these results, the analysis of structural changes of air emissions from the viewpoint of final demands of the economy was undertaken.

Major observations by the analysis are as follows. Emissions induced by consumption expenditures increased to be 57.6% of total emissions in 1995 compared to 52.9% in 1990, whereas those by public and private investments decreased from 30.0% to 26.6% in the same period. The increase of CO2 emissions induced by consumption expenditures amounts to 28 MtC (million tons of carbon) in an absolute term, which is even larger than the increase of total national emissions. Large increase in consumption-driven emissions was observed also in the period 1985-1990 which amounts to 30 MtC, whereas those in the period 1975-1985 were almost stable. Increase in the consumption-driven emissions in recent 10 years (from 1985 to 1995) accounts for as much as three quarters of total increase in national emissions.

(3) International joint study for the comparison of bulk material flow indicators

Participants to a workshop on indicators of sustainable development held in 1995 from four industrialized nations, Germany, the United States, the Netherlands and Japan agreed to launch an international collaborative study to compare their overall material flows at national level. After publishing "Resource Flows" in 1997, the first outcome of this collaborative study, collection of data and calculation of indicators for total material output flows from the economy to the nature were undertaken as a second phase of the collaborative study with Austria, Germany, the Netherlands and the United States. Data for Japan covers the period from 1975 to 1997. "The weigh of Nations", the second report by the collaborative study was published in autumn 2000.

Major observations by the joint study are as follows. The absolute level of Direct Processed Output (DPO) per capita in Japan is about 4 metric tons without oxygen and 11 metric tons with oxygen. These values are relatively small among the countries studied. Fig. 1 shows international comparison of outflow indicators. The largest output flow from the economy to the nature is emission of carbon dioxide. After CO_2, waste disposal to controlled landfill sites is the next major component of Direct Processed Output (DPO). This is of greater environmental significance than the nominal weight implies. The amount of landfill wastes was almost constant until 1990, but is now decreasing trend, thanks to waste minimization and recycling efforts. Input of food and feed are balanced by return flows of CO_2 and water after digestion. Dissipative use is another important category of output flows. Dissipative flows are dominated by applications of animal manure to fields.

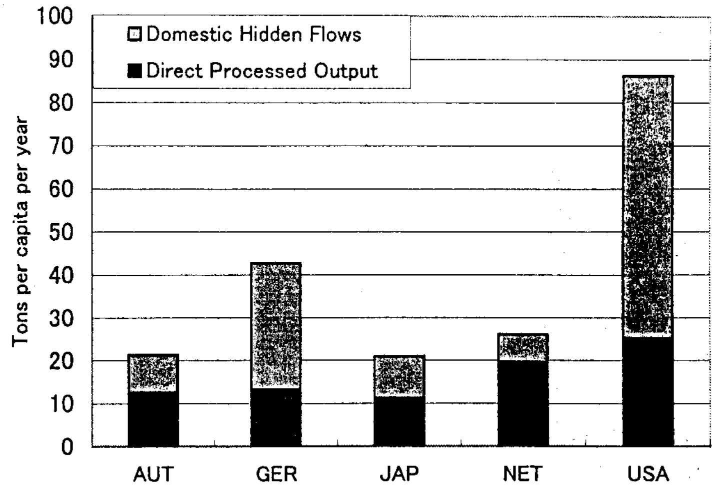

Fig. 1 International comparison of indicators of material outflows

According to the previous analysis of historical trends of inflow indicators, Japanese TMR (Total Material Requirement) per capita has shown upward trends. This coincides with the increase of waste outflows. DPO and TDO (Total Domestic Outputs, which is the sum of DPO and domestic hidden material flows such as excavated soils) in Japan grew 20 percent during the period 1975-1996. These growths occurred mainly after the late 1980s. Before then, DPO was almost constant and TDO decreased slightly.

Material output intensity, that is, DPO or TDO per constant unit of GDP declined until 1990 because of larger growth in the monetary economy than in physical throughput. However, since 1990, de-coupling between economic growth and material throughput has not been improved, because DPO and TDO have continued to increase, while economic growth has slowed down.

Net additions of materials to the stock (NAS) in the Japanese technosphere have fluctuated in accordance with patterns of governmental and private investment. NAS increased significantly in the late 1980s, then stabilized at a lower level in 1990. As much as 60 percent of direct material input (DMI) is added to the stock. This figure also has a close relation with inputs of construction materials as well as with soil excavation.

(4) Design of improved and extended framework for monetary and physical accounts

This theme was undertaken by Prof. Ariyoshi of Kumamoto University. The first year of this research was designed for the construction of the framework for environmental accounting. It contained three stages and the first stage was an introduction of the Complete SEEA, which was an extension of the SEEA with a national accounting matrix containing the complete sequence of flow and stock accounts of the SNA. The second stage was the proposal of an extended CSEEA, which included the accounts for international environmental issues. Finally, these accounting systems were further extended and elaborated, using physical accounts, such as natural resource accounts and material flow accounts. Then a comprehensive, flexible and consistent accounting framework was proposed. It was called the Global Accounting Matrices for the Environment and Economy (GAMEE), and it contained a physical accounting framework for the environment and economy (PAFEE) and a monetary accounting framework for the environment and economy (MAFEE) on a common matrix framework.

In the second year, the figures of Japanese SEEA estimated by the Economic and Social Research Institute of the Cabinet Office (formerly the Economic Research Institute of the Economic Planning Agency) were assigned to the cells of the MAFEE, and the accounting structure of the GAMEE was further elaborated. Furthermore, the DPSER indicator system proposed by the environmental accounting research meetings organized by NIES was introduced, and it was shown that the MAFEE included various DPSER indicators.

In the third year, the residual account and the environmental protection expenditure account, which have been tackled by the Economic and Social Research Institute since 1998, were explained as the satellite accounts of the SEEA, the CSEEA, and the GAMEE. Finally, the possible development of these environmental accounts including the satellite accounts was suggested.

(5) Case studies in sectoral and local levels

This theme was undertaken by Prof. Imura at Kyushu University. Several case studies have been carried out to show the usefulness of MFA in sectoral and local levels.

The first case study focused on the flow and stock of construction materials, which amounts to about half of direct material input. A method to estimate the stock of construction materials in urban areas using Geographic Information System (GIS) was developed. This method was applied to Kita-kyushu city to estimate the material stock in urban infrastructures such as road, sewage, building, and so on. Estimated stock of construction materials in the city was 126 tons per capita.

The second study focused on food, in particular, carbon and nitrogen flows associated with production, preparation, commerce, consumption, and waste treatment of the food. According to a case study for Fukuoka city, life-cycle emissions of carbon and nitrogen associated with the food system were estimated to be 1.2 x 10^6t-C, 3.5 x 10^3t-N respectively, of which 17% and 51 % were from emissions from household. It was shown that as much as 7.6 tons of carbon was required to supply 1 ton of net carbon contained on food, which indicates high dependency of food supply system on fossil fuels.

The third study focused on material flow accounting at municipal level. Total inflows and outflows were estimated using economic input-output tables, for four target cities; Kita-kyushu, Fukuoka, Beijing and Shanghai. There were large differences in material flow profiles among these cities, reflecting the stage of economic development and the industrial structure. Data availability is crucial for more detailed analysis.

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