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Summary

Japanese IO tables are one of the largest in the world. Taking advantage of this situation, highly original contributions were developed in the area of environmental IOA. This report focuses on 3EID, an IO-based database on embodied greenhouse gas GHG emissions developed in the National Institute for Environmental Studies (NIES) and waste IO (WIO) developed by Nakamura and Kondo. Besides its high level of resolution in terms of sectoral disaggregation, the originality of 3EID consists in its explicit consideration of the physical relationships between input structure and emissions, which are mostly neglected in major international IO databases with GHG emissions. WIO has integrated waste generation and recycling within the framework of extended IOA in a highly general and flexible fashion. Recently, the Japanese Ministry of the Environment (MOE) developed and published its official WIO table, the first WIO officially developed and made public.

Introduction

The purpose of this report is to present the latest state of environmentally extended Input-Output Analysis (IOA) in Japan. Japan has a rather long history of the development of IO tables tracing back to 1951 and has one of the most detailed IO tables (around 500 rows and 400 columns) in the world. Taking advantage of the availability of high-resolution IO tables, several important contributions were done in environmentally extended IO, of which the 3EID database on embodied GHG emissions and waste IO (WIO) are distinguishing. This report gives a concise account of the latest state of these two extensions.

[1] Prepared for a report of the sub-group on environmentally extended input-output within the London Group on Environmental Accounting.

3EID by NIES

The exogenous versus endogenous approach to estimate the direct emission coefficients

In general, the matrix of embodied emission coefficients R (of order $e \times n$) is given by

$$R = E(I - A)^{-1} \qquad (1)$$

where A stands for the standard $n \times n$ matrix of input coefficients (technology matrix) and E for the $e \times n$ matrix of direct emission coefficients. Practical methods of estimating matrix E can be classified into two approaches according to their methodological characteristics: the "exogenous estimate approach" and "endogenous estimate approach" (Nansai, 2009). In the former approach, E is obtained from externally available environmental data, where the term "external" refers to the fact that it is obtained independently of the IO structure represented by the technology matrix A. This approach is adopted, among others, by the World Input-Output Database (Corsatea et al., 2019) and the EIO-LCA (Weber, Chrsitopher, Matthews, Deanne, Venenkatesh, Aranya, Costello, Christine, Matthews, 2009). Critical for the soundness of the E matrix obtained by this approach is the appropriateness of the accordance between the definition of the sector's activity in the IO table and that of the emission source categories of the environmental data (Nansai, 2009).

The endogenous approach adopted by 3EID

3EID adopts the endogenous estimate approach and fully takes into account the dependence between E and the IO table, namely A, which is made possible by the availability of detailed physical IO data on GHG relevant inputs, fuels, and materials (henceforth, the term "fuel" is used to refer to all environmentally relevant inputs). Let there be n production sectors and f types of fuel input. Write Z_f^* for the $f \times n$ matrix referring to fuel input by sector in physical units, say in joule (an example is given in Table 1 for three items of iron & steel). Denote by $G = [g_{ij}]$ a matrix of order $e \times f$ with g_{ij} referring to the emission of GHG i, say CO_2, per unit input of fuel j (an example is given in Table 2). A fuel input can be used as fuel or as feedstock. Denote by $H = [h_{ij}]$ a matrix of order $f \times n$ with h_{ij}=1 if fuel input i is used as fuel in sector j, but h_{ij}=0 if it is used as feedstock in sector j. Matrix H serves as a filter to remove fuel inputs which are not used as fuel but as feedstock. The GHG emission associated with fuel input is then given by the following $e \times n$ matrix:

$$GH \odot Z_f^* \qquad (2)$$

where $\odot$ refers to the Hadamard product, that is, $H \odot Z_f^* = [h_{ij} z_{f,ij}^*]$. Dividing this matrix by the $n \times 1$ vector of output x, one obtains E, while doing so with the $n \times n$ matrix of intermediate flows in monetary units, Z, gives A (see Nansai, 2009 for further details):

$$E = GH \odot Z_f^* \hat{x}^{-1} = GH \odot A_f^* \qquad (3a)$$

$$A = Z\hat{x}^{-1} \qquad (3b)$$

If all fuel items occur in n (n distinguishes all fuel sectors), Z can be decomposed into two components, one referring to fuel inputs, Z_f (of order $f \times n$), and the rest (of order $f \times (n-f)$). Writing p_f for the f$\times$ 1 vector of the price of fuel and $\widehat{p_f}$ for its diagonalized matrix, we would then have $Z_f = \widehat{p_f} Z_f^*$, and hence

$$E = GH \odot A_f (\widehat{p_f})^{-1} \quad (4)$$

where A_f is the matrix of fuel input coefficients in monetary units given by $A_f = Z_f \hat{x}^{-1}$. In reality, n would not be detailed enough to distinguish all fuels in Z (which is the case for 3EID) and for some fuel item prices would not be available (for example, COG or BFG in Table 1), and hence (4) would not hold exactly. Still, it remains true that A_f^* provides the basic technological information about fuel input (of whatever degrees of resolution) manifested in A. The dependence of the emission coefficients matrix E on the matrix A is now obvious. Given that the elements of G are determined by the laws of physics, and H is exogenously given, E is determined by A_f^*. Whenever A_f^* changes, say, by a change in the fuel mix, E would change as well. This casts some doubts about the validity of the frequently observed practice of "structural decomposition analysis" (Hoekstra & Van Den Bergh, 2002)(Minx et al., 2011)(Su & Ang, 2012) where a change in the amount of emission is factored into a change in E and a change in $(I-A)^{-1}$ regarding as if they were independent factors .

The embodied emission intensities

3EID has been widely used (Hokazono & Hayashi, 2012), (Kawajiri et al., 2015), (Nakatani et al., 2015), with the latest application (Nansai et al., 2020). Table 3 gives the estimated values of E and R for a small selection of sectors from 3EID for the year 2011. Depending on the way imports are treated, the embodied emissions R are provided in two versions, one based on $(I-A)^{-1}$ and one based on $(I-(I-\widehat{m})A)^{-1}$ where m is an n $\times$ 1 vector with its ith element m_i referring to the share of imports in the total supply of product i. The former assumes that all imports can be domestically produced with the same domestic technology A, whereas in the latter case all imports are excluded, and domestic flows only are considered. The former could accommodate the emissions associated with imports subject to the assumption that the same technology was used in exporting countries, whereas the latter could provide accurate emissions of domestic origins. Both cases have advantages and disadvantages. Resorting to a multi-regional IO (MRIO) framework would be an ideal solution, at least, conceptually. The lack of high-resolution MRIO data comparable with the Japanese IO tables, however, implies that resorting to an MRIO would result in a substantial loss in the level of sectoral resolution. An innovative solution to get around this problem was proposed by (Nansai et al., 2009).

Waste IO

Waste and waste management in IO

Almost any economic activity generates waste of some sort. Any domesticated animals and humans produce excreta. Any durable product eventually becomes waste after the elapse of its life. Proper treatment of waste is at the core of public health. With a recent revival of the concept of circular economy (CE)Lieder and Rashid (2016) Korhonen et al. (2018), there are growing needs for comprehensive quantitative tools capable of evaluating the overall (economy-wide) environmental and economic performances of CE strategies, such as valorization, reuse, recycling and proper treatment of waste, under explicit considerations, among others, of technological, physical and institutional constraints. While IOA poses as one of the best-suited tools for such an aim, waste and waste management remain one of the least explored areas of IOA. Even for the Japanese IO tables with its remarkably high sector resolution and supplementary physical information, which make it possible to develop 3EID, application to issues of waste and waste management is hardly possible. Waste flows are not explicitly considered, and waste treatment is not distinguished by technology, such as incineration or landfill. The situation is not better for the US IO table with a similar level of sector resolution.

To date, the most widely used IO data and model involving waste and waste management is the Waste IO (WIO) originally developed by Nakamura and Kondo (Nakamura & Kondo, 2002) (see (Towa et al., 2020) for a recent extensive survey). WIO consists of an accounting framework (the WIO table) encompassing the flow of products and waste among production and waste management sectors, including waste recycling, and the associated mathematical model (the WIO model) which can be applied to LCA, MFA, and other areas of Industrial Ecology (IE). While WIO is well documented and widely used (Nakamura & Kondo, 2009)(Nakamura & Nansai, 2016) (Towa et al., 2020), a brief introduction to it is given below for comprehensiveness.

The WIO table and WIO model

Table 4 gives a schematic WIO account with n_I producing sectors (each producing a single product), n_{II} waste treatment sectors, n_y final demand sectors, and n_w waste categories. The set of n_I products is denoted by I and that of n_{II} waste treatment sectors by II. The matrices X_I, X_{II}, and Y_I refer to the flows of goods and services among production sectors, waste management sectors, and the final demand, respectively. The matrices W_k^+ and W_k^- with $k = I, II, y$ refer to the supply (generation) of and the demand (recycling) for waste in production, waste treatment, and final demand sectors.

Denote by W_k the net supply of waste obtained by subtracting the supply of waste from the demand for waste: $W_I = W_I^+ - W_I^-$, $W_{II} = W_{II}^+ - W_{II}^-$, and $W_y = W_y^+ - W_y^-$. The following balance then holds for the output of products and the amount of waste for treatment

$$X_I\iota + X_{II}\iota + Y_I\iota = x_I \qquad (5)$$

$$W_I\iota + W_{II}\iota + W_y\iota = w \qquad (6)$$

where ι refers to the unit vector of an appropriate order for summation.

Denote by x_{II} the output of waste treatment sectors, that is, the amount of waste treated by n_{II} waste treatment sectors. By definition, the sum of x_{II} is equal to the sum of w. Adopting the standard proportionality assumption of input to output, one obtains from (5) and (6) the Environmental IO (EIO)model of Leontief (Leontief, 1970) and Duchin (Duchin, 1990)

$$\begin{pmatrix} x_I \\ w \end{pmatrix} = \begin{pmatrix} A_I & A_{II} \\ G_I & G_{II} \end{pmatrix} \begin{pmatrix} x_I \\ x_{II} \end{pmatrix} + \begin{pmatrix} y_I \\ w_y \end{pmatrix} \qquad (7)$$

where G_I and G_{II} are the matrices of net-waste generation coefficients with $W_I = G_I \widehat{x_I}$ and $W_{II} = G_{II} \widehat{x_{II}}$. This system is not solvable because w occurs on the left side, while it is x_{II} that occurs on the right side. Leontief (Leontief, 1970) and Duchin (Duchin, 1990) considered the special case of $w = x_{II}$, for which the system is solvable. To be more specific, Leontief considered the case where each pollutant is exclusively and exhaustively treated by a single pollution abatement sector, and Duchin the case where each category of wastewater is exclusively and exhaustively treated by a specific treatment sector. However, such a special case hardly represents the reality of waste management. For instance, any solid waste can be disposed to a landfill, and a given waste can be submitted to a variety of treatment processes.

Nakamura (Nakamura, 1999) and Nakamura and Kondo(Nakamura & Kondo, 2002) solved this indeterminacy problem by introducing an allocation matrix $S = [s_{ij}]$ of order $n_{II} \times n_w$ with s_{ij} giving the share of waste j that is submitted to treatment process i. Multiplication of S to both sides of (6) transforms the net supply of waste into the flow of the demand for waste treatment

$$SW_I\iota + SW_{II}\iota + SW_y\iota = Sw = x_{II} \qquad (8)$$

Replacing (6) by (8) and reformulating (7) accordingly gives the following symmetric system

$$\begin{pmatrix} x_I \\ x_{II} \end{pmatrix} = \begin{pmatrix} A_I & A_{II} \\ SG_I & SG_{II} \end{pmatrix} \begin{pmatrix} x_I \\ x_{II} \end{pmatrix} + \begin{pmatrix} y_I \\ Sw_y \end{pmatrix} \qquad (9)$$

This is the WIO model. The significance of WIO consists in that it extended the standard IO to include the generation and treatment of waste, that is, the end of life phase of products. In its original form, IOA is only concerned with the production phase of products. WIO has thus managed to close the loop of a product life cycle within the framework of IOA (Suh & Nakamura, 2007).

Publicly available WIO tables

The first WIO table was developed by Nakamura and colleagues based on Japanese IO tables for the year 1995, and subsequently for the year 2000 (*WIO-WWW*). While the concept of WIO has been widely used in many countries, full implementation of WIO has been often hampered with the difficulty of obtaining high-resolution data on waste and waste management (Towa et al., 2020) (Meyer et al., 2020). A notable exception to this outside Japan is Taiwan, where WIO is used as the accounting framework in EPA's Sustainable Materials Management SMM system (Chen et al., 2017). As for the WIO data that is openly available, those developed by Nakamura and his colleagues for 1995 and 200 for Japan (WIO-WWW) had been the only ones.

This situation changed in 2011 when the Japanese Ministry of the Environment (MOE) launched a project to develop input-output tables for analysis of environmental fields including waste and waste management(*MOE*). As for the accounting and modeling framework dealing with waste and waste management, the WIO accounting system and modeling were adopted. Until it ended in the year 2017, an official WIO table for the year 2011 with 80 production sectors, nine waste treatment sectors (incineration, dehydration, concentration, shredding, filtration, composting, feed conversion, gasification, and refuse-derived fuel), and 99 waste items, was developed. Henceforth, this WIO table is termed MOE-WIO. Of the 99 waste items in MOE-WIO, 24 refer to industrial waste (waste generated from industrial processes), 24 to municipal solid waste generated from households and business sectors, and 51 to secondary wastes derived from waste treatment sectors (Table 6). To date, MOE-WIO is the only officially developed and openly available WIO table. While the EPA of Taiwan developed a large WIO table involving several hundreds of waste items and dozens of waste treatment processes, it is for internal use only and is not publicly available (Chen et al., 2017).

As for the method of data development, MOE-WIO mostly follows the exogenous approach and obtains W_I, W_{II}, and W_y based on various statistics and surveys on waste, partly augmented with numerical information obtained from a system engineering model of waste treatment. In other words, the physical relationships, or mass balances, between A and G are for the most part not explicitly considered. The situation was similar to the WIO tables developed by Nakamura and colleagues except for that they used a system engineering model of waste treatment to obtain the elements of A_{II} and G_{II}, in particular, for waste incineration, shredding, and landfilling.

Where to go

Vital for understanding the generation of process wastes and byproducts is a proper consideration of mass-balances in the relevant production processes. For instance, the amount of slag in iron production processes depends on the amount of lime entering the furnace and the amount of scrap metal in a metal production process depends, among others, on the product yield of the process. These examples vividly illustrate that the input coefficients A and waste generation coefficients G are deeply interrelated.

It is noteworthy that in their study of waste flows in global supply chains, which uses the framework of WIO, (Tisserant et al., 2017) estimated the amount of waste generated based on the mass balance of industrial processes at a level of resolution of around 140 sector classification, very much in accord with the endogenous approach. A caveat here, however, is that they used the mass balance for estimation because "data on inputs of natural resources, products, and emissions are generally of a higher quality compared to data on waste generation, which are provided by national institutions using different waste definitions, classifications, and accounting schemes" (Tisserant et al., 2017, p.630). Combined use of detailed process information involving the generation of wastes and byproducts as is commonly employed in LCA inventory analysis would be helpful.

Closely related to IOA is Material Flow Analysis (MFA), a major tool of Industrial Ecology besides Life Cycle Assessment (LCA). Fundamental to MFA is a proper consideration of mass-balances between inputs and outputs (Brunner & Rechberger, 2004). Extending the framework of WIO, (Nakamura and Nakajima, 2005) developed a mathematical model of MFA (WIO-MFA) which explicitly considers the mass-balances between inputs and outputs including waste and byproducts and applied it to the flow of copper, lead, zinc, aluminium, and iron & steel in the Japanese economy. This model was further developed to a dynamic one and applied to trace the fate of metals over time and products (Nakamura et al., 2014)(Pauliuk et al., 2017)(Nakamura et al., 2017) (see Figure 1).

Reviewing the latest developments of 3EID and WIO, one realizes that they are common in pointing to the importance of considering physical relationships between inputs and outputs including emissions, waste, and byproducts. It is hoped that IO evolves toward an integrating accounting and modeling framework encompassing both economic and physical/technological flows.

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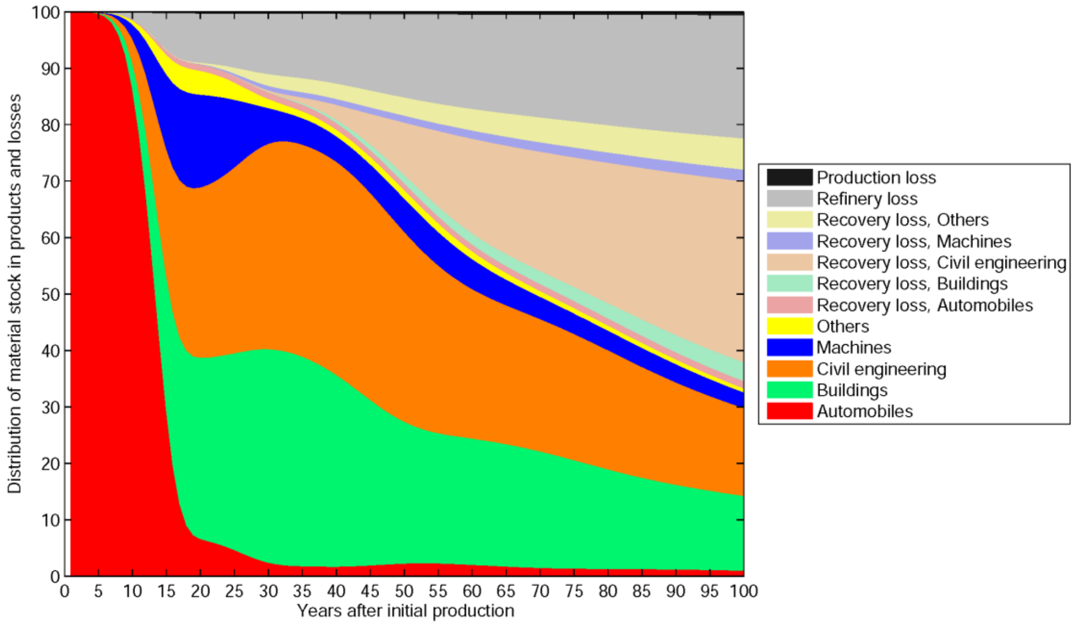

Figure 1: Transition in the composition of the stock of car steel originally used for passenger cars in products and losses. Exports are assumed to follow the same product lives and are submitted to the same EoL and recycling processes as in Japan. Taken from Figure 3 of (Nakamura et al., 2014)

Table 1: Energy consumption (an excerpt) (National Institute for Environmental Studies, 2016)

		Row code	261101	261102	261103
Column ID	Fuel and resource name	Sector name	Pig iron	Ferro alloys	Crude steel (converters)
1	Coking coal	GJ	359773420	9450142	22357779
2	Steam coal, lignite, and anthracite	GJ	0	0	0
3	Coke	GJ	118898800	9029416	2041301
4	Blast furnace coke	GJ	953337869	0	0
5	Coke oven gas (COG)	GJ	103763848	1540992	6291663
6	BFG (Consumption)	GJ	211543911	3377437	11295460
7	BFG (Generation)	GJ	-441990884	0	0
8	LDG (Consumption)	GJ	35122489	560753	1875377
9	LDG (Generation)	GJ	0	0	-73383440
10	Carbon in steel for LDG generation	GJ	-73383440	0	73383440
11	Crude oil	GJ	0	0	0
12	Fuel oil A	GJ	38162	211492	697818
13	Fuel oils B and C	GJ	11089732	5515702	1256824
14	Kerosene	GJ	0	26610	83298
15	Diesel oil	GJ	450	2288	0
16	Gasoline	GJ	0	4067	0
17	Jet fuel	GJ	0	0	0
18	Naphtha	GJ	0	0	0
19	Petroleum-based hydrocarbon gas	GJ	0	0	0
20	Hydrocarbon oil	GJ	0	0	0
21	Petroleum coke	GJ	14913701	0	0
22	Liquefied petroleum gas (LPG)	GJ	592377	79172	3853988
23	Natural gas, LNG	GJ	2787161	0	54147
24	Mains gas	GJ	8785504	1971	1878778
25	Black liquor	GJ	0	0	0
26	Waste wood	GJ	0	0	0
27	Waste tires	GJ	1802982	0	2133
28	Municipal waste	GJ	0	0	0
29	Industrial waste	GJ	0	0	0
30	Recycled plastic of packages origins	GJ	5205803	64074	327269
31	Nuclear power generation	GJ	0	0	0
32	Hydro and other power generations	GJ	0	0	0
33	Limestone	GJ	0	0	0

Table 2: CO2 emission factors of fuels and resources. 3EID (National Institute for Environmental Studies, 2016)

	Fuel and resource name	Calorific value	Unit	Emission factor	Unit
1	Coking coal	29	GJ/t	0.0899	t-CO_2/GJ
2	Steam coal, lignite, and anthracite	25.7	GJ/t	0.0906	t-CO_2/GJ
3	Coke	29.4	GJ/t	0.1077	t-CO_2/GJ
4	Blast furnace coke	29.4	GJ/t	0.1077	t-CO_2/GJ
5	Coke oven gas (COG)	21.1	GJ/1000Nm3	0.0403	t-CO_2/GJ
6	BFG (Consumption)	3410	GJ/10^6Nm3	0.1077	t-CO_2/GJ
7	BFG (Generation)	3410	GJ/10^6Nm3	0.1077	t-CO_2/GJ
8	LDG (Consumption)	8410	GJ/10^6Nm3	0.1077	t-CO_2/GJ
9	LDG (Generation)	8410	GJ/10^6Nm3	0.1077	t-CO_2/GJ
10	Carbon in steel for LDG generation	8410	GJ/10^6Nm3	0.1077	t-CO_2/GJ
11	Crude oil	38.2	GJ/kl	0.0684	t-CO_2/GJ
12	Fuel oil A	39.1	GJ/kl	0.0693	t-CO_2/GJ
13	Fuel oils B and C	41.9	GJ/kl	0.0716	t-CO_2/GJ
14	Kerosene	36.7	GJ/kl	0.0679	t-CO_2/GJ
15	Diesel oil	37.7	GJ/kl	0.0687	t-CO_2/GJ
16	Gasoline	34.6	GJ/kl	0.0671	t-CO_2/GJ
17	Jet fuel	36.7	GJ/kl	0.0671	t-CO_2/GJ
18	Naphtha	33.6	GJ/kl	0.0666	t-CO_2/GJ
19	Petroleum-based hydrocarbon gas	44.9	GJ/1000Nm3	0.0519	t-CO_2/GJ
20	Hydrocarbon oil	41.7	GJ/kl	0.0762	t-CO_2/GJ
21	Petroleum coke	29.9	GJ/t	0.0930	t-CO_2/GJ
22	Liquefied petroleum gas (LPG)	50.8	GJ/t	0.0598	t-CO_2/GJ
23	Natural gas, LNG	54.6	GJ/t	0.0494	t-CO_2/GJ
24	Mains gas	44.8	GJ/1000Nm3	0.0501	t-CO_2/GJ
25	Black liquor	13.2	GJ/t (dry)	0.0953	t-CO_2/GJ
26	Waste wood	16.3	GJ/t (dry)	0.1120	t-CO_2/GJ
27	Waste tires	33.2	GJ/t	0.0523	t-CO_2/GJ
28	Municipal waste	10.7	GJ/t	0.0259	t-CO_2/GJ
29	Industrial waste	16.7	GJ/t	0.0419	t-CO_2/GJ
30	Recycled plastic of packages origins	48	GJ/t	0.0666	t-CO_2/GJ
31	Nuclear power generation	3600	GJ/GWh		-
32	Hydro and other power generations	3600	GJ/GWh		-
33	Limestone	0	-	0.440	t-CO_2/t

Table 3: Embodied energy and emission intensities (an excerpt) (National Institute for Environmental Studies, 2016)

	Unit direct energy consumption	Unit direct CO2 emission	Embodied energy intensity (I-A)-1	Embodied CO2 emission intensity (I-A)-1	Embodied energy intensity (I-(I-M)A)-1	Embodied CO2 emission intensity (I-(I-M)A)-1
Sector name	GJ/million yen	t-CO2/million yen	GJ/million yen	t-CO2/million yen	GJ/million yen	t-CO2/million yen
Pig iron	609.15	61.04	715.50	68.49	666.60	65.09
Ferroalloys	115.86	10.70	209.70	16.94	172.70	14.35
Crude steel (converters)	13.89	2.54	439.30	42.73	396.40	39.49
Household air-conditioners	1.13	0.06	42.30	2.88	30.00	2.04
Passenger motor cars	1.06	0.06	50.80	3.61	40.20	2.86
Residential construction (wooden)	0.81	0.05	28.20	2.21	22.20	1.79
Residential construction (non-wooden)	1.87	0.12	38.50	3.31	32.00	2.83
Non-residential construction (wooden)	0.93	0.06	29.40	2.34	23.70	1.94
Non-residential construction (non-wooden)	1.93	0.14	39.40	3.33	32.80	2.84
Electricity	437.31	24.64	479.10	27.34	465.30	26.36

Table 4: A schematic WIO account

	Goods production (n_I)	Waste treatment (n_{II})	Final demand (n_y)
Goods (n_I)	X_I	X_{II}	Y_I
Waste supply (n_w)	W_I^+	W_I^+	W_y^+
Waste demand (n_w)	W_I^-	W_{II}^-	W_y^-

The letter in the parenthesis refers to the number of sectors/items.

Table 5: The waste flow in the Waste IO table, Japan 1995

	AGR	MIN	FOD	WOD	CHE	CEM	MET	MEP	MCN	CNS	UTL	SRV	TRN	INC	LND	SHR	FDM
	Waste flow																
grb	0	0	0	0	0	0	0	0	0	0	0	5999	0	0	0	0	10000
ppr	191	10	560	-11720	525	292	108	387	1113	1322	182	9367	913	0	0	170	17634
pls	258	4	392	606	-1012	77	7	709	902	1020	39	2572	281	0	0	304	4330
mtl	3	1	37	134	-84	10	-40151	2570	5446	7594	14	542	47	0	0	3765	22777
gls	3	1	-4403	34	137	-2137	97	331	211	1771	63	5354	53	0	0	113	3457
wds	19854	0	1454	2627	90	0	0	0	0	3233	0	175	0	0	0	1091	857
ash	0	4714	222	987	1593	-11627	2213	15122	1784	-9174	4753	40	5	4588	0	0	0
sld	-5743	4512	2431	7028	4023	-989	334	1372	695	11747	3843	381	34	0	0	0	0
oil	6	3	1376	155	856	91	369	1601	1869	87	20	987	160	0	0	0	0
dbr	0	139	23	33	204	341	211	657	463	14200	154	681	382	0	0	0	0
blk	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3282
ELV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5020
dst	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1739	0
	Waste flow converted to the damend for waste treatment																
INC	20,190	14	3,555	-7,771	837	334	200	2,437	3,481	5,263	215	16,874	1,178	0	0	1,429	29,013
LND	-5,619	9,374	-1,463	7,654	5,492	-14,281	-37,016	20,314	9,002	26,533	8,864	9,224	698	4,183	0	5,752	30,042
SHR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8,302

	The allocation matrix (transposed) to convert the flow of waste into the demand for waste trteatment												
	garbage	ıaper wast	lastic wast	metal scrap	glass scrap	aste wooc	ash	sludge	waste oil	truction w	ulky wast	life auton	dust
Incineration	0.90	0.93	0.59	0.01	0.04	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
Landfill	0.10	0.07	0.41	0.99	0.96	0.00	1.00	1.00	0.00	1.00	0.00	0.00	1.00
Shredding	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.00

AGR: the primary sector, MIN: mining, FLD: food, WOD: wood & paper, CHE: chemical industry, CEM: cement & glass, MET: metals, MEP: metal products, MCN: machinery, CNS: construction, UTL: utilities, SRV: services, TRN: transport.

Table 6: Waste items in MOE-WIO

	Primary waste	Secondary waste derived from*
1	Cinders	i, d
2	Sludge	d
3	Waste oil	f, c
4	Waste acid	
5	Waste alkali	
6	Waste plastics	s
7	Waste paper	s
8	Wood waste	s
9	Waste fiber	s
10	Animal & plant residue	d
11	Animal solid waste	s
12	Waste rubber	s
13	Iron scrap	s
14	Copper scrap	s
15	Aluminum scrap	s
16	Lead scrap	s
17	Zinc scrap	s
18	Other NF metal scrap	s
19	Glass etc. scrap	s
20	Slag	s
21	Construction waste	s
22	Livestock excreta	c
23	Livestock corpses	s
24	Dust	d
25	Kitchen waste	
26	Other flammable waste	s
27	OA paper	s
28	Newspaper etc.	s
29	Paper drink box	s
30	Paper container & package	s
31	Styrofoam (white)	s
32	Plastic container & package	s
33	PET bottles	s

34	Steel can	s
35	Aluminum can	s
36	Other metals	s
37	Glass bottles	s
38	Wooden bulky waste	s
39	Small home electric appl.	s
40	Other bulky waste	s
41	Other nonflammable waste	s
42	TV (CRT)	
43	TV (LCD)	
44	Air conditioners	
45	Refrigerators & freezers	
46	Washing machines & dryers	
47	Automobiles	s
48	PC	
49		Compost (composting)
50		Feed (feed conversion)
51		Waste liquid (gasification
52		Fuel (refuse-derived fuel)
53		Wires (s)
54		Electric circuit (s)
55		Automobile parts (s)
56		Shredding residues
57		Automobile shredding residues

*The third column gives secondary waste that is derived when the primary waste was submitted to designated treatment processes denoted by i for incineration, d for dehydration, f for filtration, c for concentration, and s for shredding. The last nine items occur only as secondary waste.