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Application of the Input-Output Approach in Environmental Analysis in LCA*

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Abstract

Life cylce assessment evaluates the total burden on the environment in the life cycles of goods and services. However, to obtain the cumulative effects attributed by each material inputs necessary involved high cost. As the quality of the analysis results are not positively related to the amount of time and cost spent on the estimation, this undermines the incentive to carry out LCA investigation. Hence, in this paper, we make use of the input-output tables that have been extended for environmental analysis in LCA analysis. For the production of automobiles, we found that the indirect effect it contributed is greater than the direct effect, and the total CO_2 emission from general inputs such as wholesale trade and advertising are in fact greater than that from the prodution of the car body.

1. LCA and Input-Output Analysis

Recently, there has been an attempt to capture the impact of the production of goods and services on the environment using the concept of Life Cycle Assessment(LCA). LCA is an attempt to evaluate the burden effect caused by the production of a good on the environment, and it involves the retrospective accumulation of effects on the environment produced by energy and materials required directly and indirectly in the production of a particular good. The accumulation of these effects involves firstly, measuring the impact of energy consumption on the environment (e.g. CO_2 emission), secondly, measuring the impact on the environment from energy consumption occurs during the production of the various energies and materials required in the production process, and so on, retrospectively.

However, it is almost impossible for an individual firm to know the effect its products exert on the environment as its products pass through many hands. While it may not be difficult to calculate the burden to the environment generated by the production process within the firm, it is difficult for the firm to know the burden on the environment produced in the manufacturing of parts and components and raw materials that are supplied by other firms. Even if it is possible to obtain these information, the range is extremely limited considering the human effort put into it and we may also be forced to calculate the effect of the burden arbitrarily in actual circumstances. Moreover, if the linkage effects of the retrospective accumulation are omitted, this will result in an underestimation of the burden to the environment. As the greater the amount of time and cost spent, the worse the results obtained, this undermines the incentives to carry out the investigation.

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On the other hand, in the case of input-output analysis in economics, while it only takes into account the national average, arbitrariness is reduced if the tables from a particular year is used as a base, as the retrospective accumulation of the burden effect on the environment and its linkages could be calculated till the very final stage. Hence, in this paper, we introduce the LCA analysis using the input-output table that has been extended for environmental analysis.

Although we only consider CO_2 as the burden to the environment in this paper, similar calculations could also be applied to NOx and SOx. Further, due to the limitation in products data, we only consider products manufactured domestically. However, as this method of analysis could be easily extended to other kinds of burden on the environment and linkage effects abroad, it could be considered as a useful prototype for analysis along this line of approach.

2. Calculating the burden on the environment based on input-output analysis

We assumed that n types of goods and services are produced in the economy. These goods and services are used in the production of other goods and services, and they are also consumed as final demand or used as investment goods. The relationship in the quantities of these inputs and outputs are illustrated in matrix forms which constitute the input-output tables.

The quantity of input requires in the production of 1 unit of the various components of the matrices in the input-output tables are written as a_{ij}, i.e. the input coefficient. The value of a_{ij} refers to the quantity of the ith good required in the production of 1 unit of the jth good. Here, both the values of i and j, which represent the number of goods and services, take values from 1 to n. The input coefficients could also be rewritten in the following form,

$$\mathbf{A} = \begin{pmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{pmatrix} \quad : \text{Input coefficient matrix} \tag{1}$$

Further, we let the burden on the environment generated by the production of 1 unit of the jth good as e_j. For convenience in calculation, it is written in the following diagonal matrix form,

$$\mathbf{e} = \begin{pmatrix} e_1 & & 0 \\ & \ddots & \\ 0 & & e_n \end{pmatrix} \quad : \text{Environmental burden diagonal matrix} \tag{2}$$

Let $\mathbf{f} = \begin{pmatrix} f_1 \\ \vdots \\ f_n \end{pmatrix}$ be the demand on various goods for the production of a particular good. Here, the direct burden on the environment arises from the production of vector $\mathbf{f}$ of goods and services inputs is $\mathbf{e}\cdot\mathbf{f}$.

For example, the burden on the environment generated by the production of 1 unit (1 million yen unit in 1985 fixed prices) of automobile (kth good) is written as follows,

CO_2 Total	105kg	383kg	571kg
CO_2 Cummulative Total	105kg	488kg	1059kg

Figure 1: CO_2 Emission from per unit producti

nd indirect effect>	<3rd indirect effect>	<4th indirect effect>	<5th indirect effect>
01 Natural gas:2kg	072101 Crude petroleum:7kg	072101 Crude petroleum:7kg	061201 Non ferrous metal ores:2kg
01 Foreign paper and Japanese paper:2kg	073101 Natural gas:2kg	073101 Natural gas:2kg	
01 Industrial soda chemicals:2kg	151401 Yarn and fabric dyeing and finishing (:2kg		071101 Coal mining:1kg
02 Inorganic pigment:3kg	181101 Pulp:2kg	181101 Pulp:8kg	072101 Crude petroleum:7kg
09 Other industrial inorganic chem.:3kg	181201 Foreign paper and Japanese paper:8kg	181201 Foreign paper and Japanese paper:7kg	073101 Natural gas:2kg
01 Petrochemical basic products:1kg	181301 Paperboard:2kg	181301 Paperboard:3kg	181101 Pulp:8kg
01 Aliphatic intermediates:2kg	202101 Industrial soda chemicals:3kg	202101 Industrial soda chemicals:3kg	181201 Foreign paper and Japanese
02 Cyclic intermediates:1kg	202902 Inorganic pigment:1kg	202909 Other industrial inorganic chem.:3kg	181301 Paperboard:3kg
01 Synthetic rubber:10kg	202909 Other industrial inorganic chemical:4kg	203101 Petrochemical basic products:7kg	202101 Industrial soda chemicals:2k
09 Other industrial organic chem.:1kg	203101 Petrochemical basic products:6kg	203102 Petrochemical aromatic products:2kg	202909 Other industrial inorganic c
01 Thermo setting resin:2kg	203102 Petrochemical aromatic products:1kg	203201 Aliphatic intermediates:6kg	203101 Petrochemical basic product
02 Thermoplastics resin:9kg	203201 Aliphatic intermediates:6kg	203202 Cyclic intermediates:5kg	203102 Petrochemical aromatic proc
09 Other resin:2kg	203202 Cyclic intermediates:4kg	203301 Synthetic rubber:1kg	203201 Aliphatic intermediates:4kg
09 Other final chemical products:2kg	203301 Synthetic rubber:4kg	204101 Thermo setting resin:1kg	203202 Cyclic intermediates:3kg
01 Petroleum refinery products (inc. grease):10kg	203909 Oth. industrial organic chem.:1kg	204102 Thermoplastics resin:4kg	204102 Thermoplastics resin:2kg
01 Coal products:1kg	204101 Thermo setting resin:3kg	211101 Petroleum refinery products:11kg	211101 Petroleum refinery products
01 Plastic products:5kg	204102 Thermoplastics resin:8kg	212101 Coal products:12kg	212101 Coal products:14kg
09 Other rubber products:3kg	204109 Other resin:2kg	221101 Plastic products:1kg	252101 Cement:2kg
01 Sheet glass and safety glass:6kg	205102 Synthetic fibers:1kg	252101 Cement:3kg	259909 Miscell. ceramic, stone and
09 Other glass and glass products:2kg	207909 Other final chemical products:1kg	259909 Misc. ceramic, stone and cla:10kg	261101 Pig iron:185kg
09 Miscellaneous ceramic, stone and clay:14kg	211101 Petroleum refinery products:11kg	261101 Pig iron:90kg	261102 ferro alloy:8kg
01 Hot rolled steel:9kg	212101 Coal products:5kg	261102 ferro alloy:4kg	261103 Crude steel:7kg
01 Cold finished steel:26kg	221101 Plastic products:2kg	261103 Crude steel:16kg	262101 Hot rolled steel:4kg
02 Coated steel:4kg	231909 Other rubber products:1kg	262101 Hot rolled steel:9kg	262301 Cold finished steel:2kg
01 Cast and forged steel:5kg	251101 Sheet glass and safety glass:1kg	262301 Cold finished steel:5kg	263103 Cast and forged materials(i
03 Cast and forged materials(iron):91kg	252101 Cement:3kg	263103 Cast and forged materials(iron):12kg	271104 Aluminium:2kg
04 Iron and steel shearing and slitting:2kg	259909 Misc. ceramic, stone & clay:18kg	271101 Copper:1kg	271109 Other non ferrous metals:2k
09 Other steel products:1kg	261101 Pig iron:45kg	271102 Lead(inc.ragenerated lead):1kg	511100 Electric power:94kg
01 Copper:4kg	261103 Crude steel:7kg	271103 Zinc(inc.ragenerated zinc):2kg	511104 Self power generation:41kg
02 Lead(inc.ragenerated lead):6kg	262101 Hot rolled steel:22kg	271104 Aluminium:5kg	521202 Other sanitary services (ind
09 Other non ferrous metals:5kg	262301 Cold finished steel:11kg	271109 Other non ferrous metals:3kg	712201 Road freight transport:5kg
02 Rolled aluminium products:2kg	262302 Coated steel:3kg	354103 Motor vehicle parts and access.:2kg	713101 Self passenger trans by pri
03 Non ferrous metal casting and forging:6kg	263101 Cast and forged steel:2kg	511100 Electric power:134kg	713201 Self freight trans. by privat
09 Other non ferrous metal prod.:1kg	263103 Cast and forged materials(iron):38kg	511104 Self power generation:42kg	714201 Coastal and inland water tr
09 Other metal products:2kg	271101 Copper:2kg	521202 Other sanitary services(ind.):4kg	715101 Air transport:2kg
02 Bearings:2kg	271102 Lead(inc.ragenerated lead):2kg	611101 Wholesale trade:1kg	900000 :5kg
06 Electrical equipment for internal comb:3kg	271103 Zinc(inc.ragenerated zinc):4kg	712201 Road freight transport:8kg	
02 Internal combustion engine for motor vehicles:8kg	271104 Aluminium:7kg	713101 Self pass. trans. by private:9kg	
03 Motor vehicle parts and accessories:24kg	271109 Other non ferrous metals:5kg	713201 Self freight trans. by private:9kg	
00 Electric power:208kg	272203 Non ferrous metal casting etc.:2kg	714201 Coastal and inland water trans.:4kg	
04 Self power generation:2kg	342106 Elec. equip. for internal comb:1kg	715101 Air transport:3kg	
02 Other sanitary services (industrial):5kg	354102 Int. combustion engine for motor:3kg	822201 Self research:1kg	
01 Wholesale trade:4kg	354103 Motor vehicle parts and access.:7kg	851909 Other business services:1kg	
01 Bus transport:1kg	511100 Electric power:179kg	900000 :8kg	
02 Hird car and taxi transport:2kg	511104 Self power generation:22kg		
01 Road freight transport:14kg	521202 Other sanitary services (ind.):4kg		
01 Self passenger transport by private motor:12kg	611101 Wholesale trade:2kg		
01 Self freight transport by private motor:12kg	712102 Hird car and taxi transport:1kg		
01 Coastal and inland water trans.:4kg	712201 Road freight transport:11kg		
01 Air transport:5kg	713101 Self pass. transport by private:11kg		
01 Self research:8kg	713201 Self freight trans. by private:11kg		
09 Other business services:3kg	714201 Coastal and inland water trans.:5kg		
00 :17kg	715101 Air transport:4kg		
	822201 Self research:3kg		
	851909 Other business services:2kg		
	900000 :13kg		

571kg	576kg	507kg	484kg
1059kg	1635kg	2142kg	2626kg

m per unit production of automobile

th indirect effect>	<6th indirect effect>	<7th indirect effect>	<8th indirect effect>
201 Non ferrous metal ores:2kg	071101 Coal mining:2kg		
101 Coal mining:1kg	072101 Crude petroleum:6kg	072101 Crude petroleum:4kg	
101 Crude petroleum:7kg	073101 Natural gas:1kg		072101 Crude petroleum:3kg
101 Natural gas:2kg	181101 Pulp:5kg	181101 Pulp:3kg	
101 Pulp:8kg	181201 Foreign paper and Japanese paper:3kg		
201 Foreign paper and Japanese paper:5kg	181301 Paperboard:2kg	181201 Foreign paper and Japanese paper:2kg	181101 Pulp:2kg
301 Paperboard:3kg	202101 Industrial soda chemicals:1kg	203101 Petrochemical basic products:1kg	
101 Industrial soda chemicals:2kg	202909 Other industrial inorganic chem.:1kg		
909 Other industrial inorganic chem.:2kg	203101 Petrochemical basic products:3kg	203201 Aliphatic intermediates:1kg	211101 Petroleum refinery product
101 Petrochemical basic products:5kg	203102 Petrochemical aromatic products:1kg		
102 Petrochemical aromatic products:2kg	203201 Aliphatic intermediates:2kg	211101 Petroleum refinery products:4kg	
201 Aliphatic intermediates:4kg	203202 Cyclic intermediates:1kg		212101 Coal products:5kg
202 Cyclic intermediates:3kg	211101 Petroleum refinery products:7kg	212101 Coal products:11kg	
102 Thermoplastics resin:2kg	212101 Coal products:21kg		
101 Petroleum refinery products:9kg	252101 Cement:2kg	252101 Cement:1kg	259909 Miscell. ceramic, stone and
101 Coal products:14kg	259909 Miscell. ceramic, stone and clay:4kg		
101 Cement:2kg	261101 Pig iron:78kg	259909 Miscell. ceramic, stone and clay:2kg	
909 Miscell. ceramic, stone and cla:8kg	261102 ferro alloy:4kg		261101 Pig iron:14kg
101 Pig iron:185kg	261103 Crude steel:3kg	261101 Pig iron:34kg	
102 ferro alloy:8kg	262101 Hot rolled steel:2kg		
103 Crude steel:7kg	263103 Cast and forged materials(iron):1kg	261102 ferro alloy:2kg	511100 Electric power:22kg
101 Hot rolled steel:4kg	271104 Aluminium:1kg		
301 Cold finished steel:2kg	511100 Electric power:63kg	261103 Crude steel:1kg	
103 Cast and forged materials(iron):4kg	511104 Self power generation:30kg		511104 Self power generation:12kg
104 Aluminium:2kg	521202 Other sanitary services (ind.):2kg	511100 Electric power:39kg	
109 Other non ferrous metals:2kg	712201 Road freight transport:3kg		
100 Electric power:94kg	713101 Self passenger trans by private:4kg	511104 Self power generation:18kg	712201 Road freight transport:1kg
104 Self power generation:41kg	713201 Self freight trans. by private:5kg		
202 Other sanitary services (ind.):3kg	714201 Coastal and inland water trans.:2kg	521202 Other sanitary services (ind.):1kg	
201 Road freight transport:5kg	715101 Air transport:1kg		713101 Self passenger trans. by pr
101 Self passenger trans by private:6kg	900000 :3kg	712201 Road freight transport:2kg	
201 Self freight trans. by private:7kg			
201 Coastal and inland water trans.:3kg		713101 Self passenger trans. by private:3kg	713201 Self freight trans. by priva
101 Air transport:2kg		713201 Self freight trans by private:3kg	
000 :5kg			900000 :1kg
		714201 Coastal and inland water trans.:1kg	
		900000 :2kg	
484kg	282kg	156kg	83kg
2626kg	2907kg	3063kg	3146kg

Figure 1: CO_2 Emission from per unit production of automobile(Continued)

irect effect>	<8th indirect effect>	<Total effect>
		071101 Coal mining:9kg 072101 Crude petroleum:41kg
e petroleum:4kg		073101 Natural gas:11kg
	072101 Crude petroleum:3kg	111901 Salt:4kg
:3kg		151401 Yarn,fabric dyeing,finishing:4kg 181101 Pulp:31kg
		181201 Foreign and Japanese paper:28kg
gn paper and Japanese paper:2kg		181301 Paperboard:13kg 202101 Industrial soda chemicals:13kg
	181101 Pulp:2kg	202902 Inorganic pigment:5kg
ochemical basic products:1kg		202909 Other ind. inorganic chem.:15kg
		203101 Petrochemical basic products:24kg 203102 Petrochemical aromatic products:9kg
natic intermediates:1kg	211101 Petroleum refinery products:3kg	203201 Aliphatic intermediates:22kg
		203202 Cyclic intermediates:15kg 203301 Synthetic rubber:16kg
oleum refinery products:4kg		204101 Thermo setting resin:8kg
	212101 Coal products:5kg	204102 Thermoplastics resin:27kg
products:11kg		211101 Petroleum refinery products:61kg 212101 Coal products:74kg
		221101 Plastic products:13kg
ent:1kg		231101 Tyres and inner tubes:5kg 251101 Sheet glass and safety glass:41kg
	259909 Miscell. ceramic, stone and clay:1kg	252101 Cement:14kg
ell. ceramic, stone and clay:2kg		259909 Miscell. ceramic, stone & clay:60kg
		261101 Pig iron:421kg 261102 ferro alloy:19kg
ron:34kg	261101 Pig iron:14kg	261103 Crude steel:36kg
		262101 Hot rolled steel:48kg 262301 Cold finished steel:47kg
alloy:2kg		262302 Coated steel:8kg
	511100 Electric power:22kg	263101 Cast & forged steel:9kg 263103 Cast & forged materials(iron):148kg
le steel:1kg		271101 Copper:9kg
		271102 Lead(inc.ragenerated lead):10kg
tric power:39kg	511104 Self power generation:12kg	271103 Zinc(inc.ragenerated zinc):8kg 271104 Aluminium:17kg
		271109 Other non ferrous metals:16kg
power generation:18kg		272203 Non ferrous metal casting etc.:9kg 342106 Elec. equip. for internal comb:7kg
	712201 Road freight transport:1kg	351101 Passenger cars:105kg
r sanitary services (ind.):1kg		354101 Motor vehicle bodies:42kg
		354102 Internal combustion engine:38kg 354103 Motor vehicle parts and access.:88kg
l freight transport:2kg	713101 Self passenger trans. by private:2kg	511100 Electric power:888kg
		511104 Self power generation:183kg 521202 Other sanitary services (ind.):29kg
passenger trans. by private:3kg		611101 Wholesale trade:16kg
		712101 Bus transport:4kg
freight trans by private:3kg	713201 Self freight trans. by private:2kg	712102 Hird car and taxi transport:6kg 712201 Road freight transport:64kg
		713101 Self pass. trans. by private:52kg
tal and inland water trans.:1kg		713201 Self freight trans by private:54kg 714201 Coastal & inland water trans.:24kg
	900000 :1kg	715101 Air transport:23kg
		822201 Self research:23kg
		851909 Other business services:13kg 900000 :52kg

kg	83kg	3241kg
3kg	3146kg	3241kg

roduction of automobile(Continued)

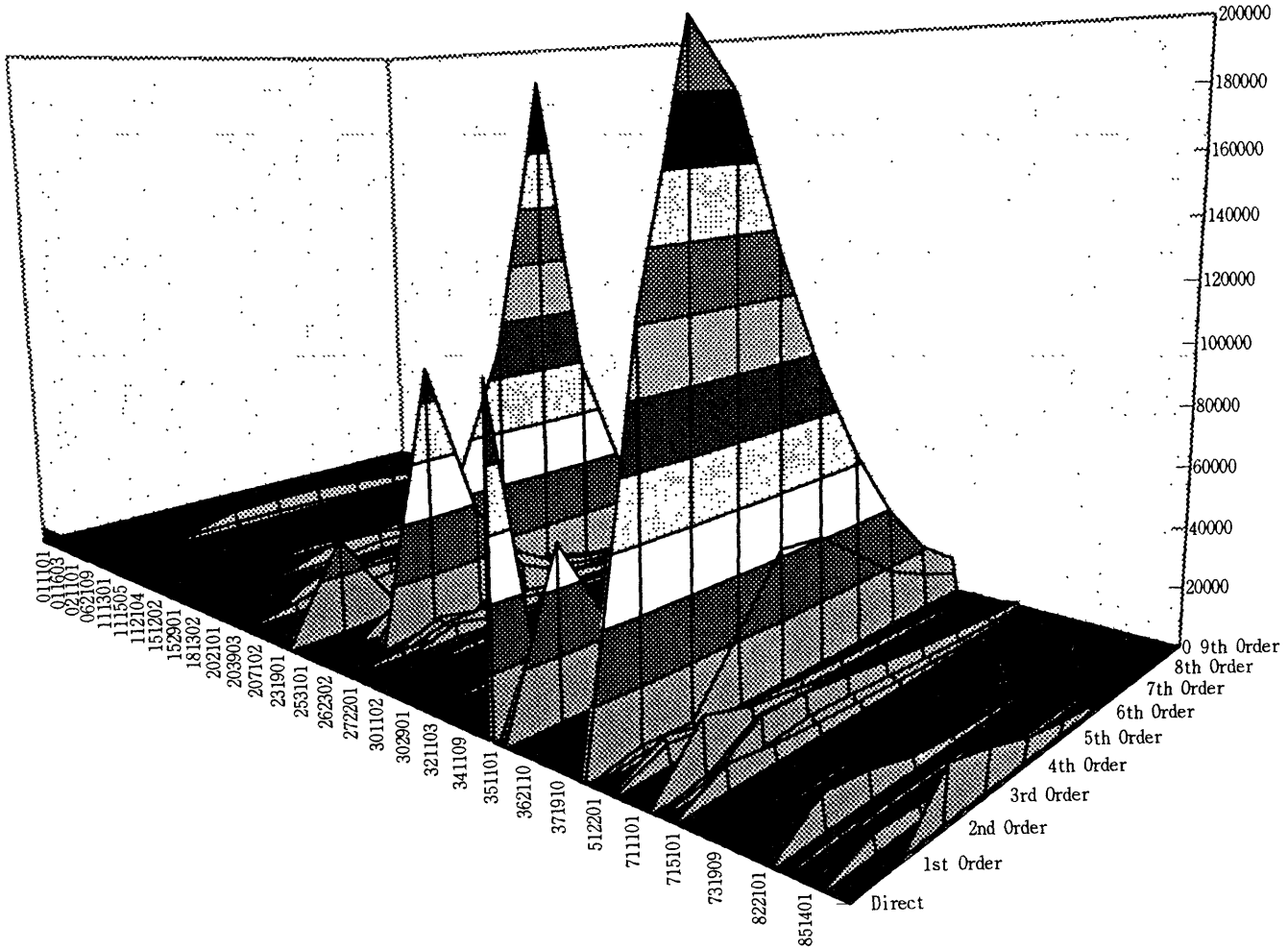

Figure 2: Process of CO_2 emission induced from per unit production of automobile

$$\mathbf{e_k} = \begin{pmatrix} e_1 & & \\ & \ddots & \\ 0 & & e_n \end{pmatrix} \begin{pmatrix} 0 \\ \vdots \\ 1 \\ \vdots \\ 0 \end{pmatrix} \tag{3}$$

This is the direct burden effect on the environment.

Next, for the first order indirect effect, the production of demand $\mathbf{f}$ requires addition production $\mathbf{Af}$, which is used as intermediate good. Therefore, the first order indirect burden effect on the environment amounts to $\mathbf{e} \cdot \mathbf{Af}$. Within which, its linkage effect on intermediate goods is again linked to the second order indirect effect. As the production of $\mathbf{Af}$, in turns requires intermediate good, $\mathbf{AAf} = \mathbf{A^2f}$, the second order indirect effect on the environment amounts to $\mathbf{e} \cdot \mathbf{A^2f}$.

The above effects could be summarized as follows,

$$\mathbf{x} = \mathbf{f} + \mathbf{Af} + \mathbf{A^2f} + \cdots = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{f} \tag{4}$$

where $\mathbf{x}$ is called the total production inducement vector. The total burden on the environment is thus written as

$$\mathbf{e} \cdot \mathbf{x} = \mathbf{e} \cdot \mathbf{f} + \mathbf{e} \cdot \mathbf{Af} + \mathbf{e} \cdot \mathbf{A^2f} + \cdots = \mathbf{e} \cdot (\mathbf{I} - \mathbf{A})^{-1}\mathbf{f} \tag{5}$$

where $(\mathbf{I} - \mathbf{A})^{-1}$ is the Leontief inverse matrix. The Leontief inverse matrix, being the sum of an unlimited number of columns, is equivalent to the retrospective accumulation of the linkage effects of the intermediate goods to the very last stage. It is worth noting that due to the unlimited number of items to be included in the summation, accumulation could only be carried out within a small range. Further, it could also be proved that the inverse matrix exists under normal conditions.

3. The production of automobile: an example

Given the demand $\mathbf{f}$ of the various goods, the burden on the environment generated directly and indirectly by the intermediate goods could be calculated by $\mathbf{e} \cdot (\mathbf{I} - \mathbf{A})^{-1}\mathbf{f}$. In the following section, we use the production of 1 unit (1 million yen) of automobile as an illustration (The details are based on the 440 sectors table in the 1985 Input-output Tables for Environmental Analysis which we compiled[1]. Figure 1 and 2 shows the calculation results of the CO_2 emission from per unit production of automobile. Due to the limits of space, Figure 1 focuses on items which their indirect effects have an emission of more than 1kg and total effects that exceed 4kg.

Firstly, for the direct effect, the production activities of a 1 million yen unit of automobile induced a CO_2 emission of 105kg. Various types of parts and components, and energy are used in the production of automobiles. From the perspective of the emission of CO_2, the production of plastic, tyres and inner tube, sheet glass, motor vehicle bodies, internal combustion engine for motor vehicles induce a larger emission comparatively. In addition, high CO_2 emission is induced from electric power generation and road freight transport. The total first order indirect effect induces a CO_2 emission of 383kg.

[1] See Yoshioka et al.(1992a) and Hayami et al.(1993).

In the next round of the linkage effect, intermediate goods are again required in the production of the goods in the first order indirect effect. Here, a high level of CO_2 is emitted in the production of cold finished steel and cast iron. Moreover, electric power generation, as a general input, has a CO_2 emission of 208kg. Hence, a total of 571kg of CO_2 is emitted in the second order indirect effect. It should be noted that the peaks in CO_2 emission for the various intermediate goods are different. For instance, the peak of CO_2 emission for electric power generation occurs in the second order effect whereas the peak for road freight transport occurs in the first order effect. While it is relatively easy to estimate the peaks for car body or internal combustion engine, it is difficult to estimate the required production of inputs used in the manufacturing of the various kinds of intermediate goods demanded simultaneously. In the calculation process of the second order indirect effect, in trying to know the quantity of the ith good required in the production of the jth good, we have to aggregate the derived demand in the production of the ith good due to jth good, through the linkage effect on the kth good. In other words, the calculation involves $\sum_{k=1}^{440} a_{ik}a_{kj}$(440×440 =193,600 items in total), to obtain the CO_2 emission induced in the production of the jth good. While the retrospective accumulation method is simple, it is clear that an enormous amount of calculation is involved in the estimation of the second order indirect effect alone.

Further, as for the third order indirect effect, items such as crude oil, pulp, dyeing and finishing, cement, crude steel, zinc, and aluminum induced an emission of more than 1kg, and cold finished steel and cast iron required in the second order indirect effect have great inducement effect on the production of pig iron and hot rolled steel. While the CO_2 emission from electric power generation remains large at 179kg, it is on a decreasing trend. On the contrary, emission from self-power generation is on the increase. The total emission of CO_2 in the third order effect amounts to 576kg, the highest level of emission within the different stages considered.

For the fourth order indirect effect, CO_2 emissions from crude petroleum, coal products, pig iron and crude steel increased. Emission peaks are located for pulp, crude steel and self-power generation. The quantity of CO_2 emission from transport related activities should not be neglected, although it is on a decreasing trend.

For the inducement effect after the fourth order, the emission peak of pig iron occurs at the fifth order indirect effect, whereas the emission peak of coal products (coke) is found to occur at the sixth order. Besides, the peak of ferro alloy (8kg) also occurs at the fifth order. The total CO_2 emission amount to 484kg and 282kg at the fifth and the six order effect, respectively, while declining thereafter. The cumulative total upto the sixth order effect amount to 2,907kg, which is equivalent to about 90% of total cumulative emission of 3,421kg obtained through the inverse matrix. However, the emission of CO_2 continues until the very last stage for the case of petroleum related products, pulp, pig iron, power generation and transport related sectors.

4. An evaluation of the total effect

It is found that in terms of the total cumulative effect, 3.2 tons of CO_2 is emitted in the production of per unit of automobile. The characteristics of the total cumulative effect could be summarized as follows. Firstly, electric power generation has the highest level, 888kg of CO_2 emission, follow by pig iron (421kg), self-power generation (183kg), and cast iron (148kg). Secondly, as the direct effect contributed by automobile amount to only 105kg, the indirect effect it generated is much larger. Thirdly, CO_2 emission from the transport sector is large, as the total emission from bus transport, hired car & taxi

transport, road freight transport, self-passenger transport and self-freight transport by private motor car, coastal and inland water transport, and air transport amount to 227kg. The CO_2 emission from these sectors are rather constant at all stages. Moreover, we should not ignore electric power generation and other general inputs that are required in all the manufacturing processes of various products. Fourthly, the accumulation of CO_2 emission from production activities such as salt, dyeing and finishing, inorganic pigment, wholesale trade and advertising, which we are likely to neglect could also sum up to a considerable amount. In fact, the total emission from these activities is about the same magnitude as the emission from the production of the car body, and wholesale trade and advertising could be considered as general inputs.

With regards to efficiency in production processes which consume a large amount of energy, Japan is quite advance among the industrial countries. However, it should be noted that transport, distribution and services are general inputs, just as the case of electricity or iron, required in the production of all types of goods. Therefore, it is a characteristic of general inputs that they are induced largely by the production of other goods. As it is also shown in our calculation, their effects should not be ignored. However, the efficiency of these services related sectors have not received much attention in Japan.

5. Towards LCA

For other goods and services, we have also calculated the CO_2 emission from the production of intermediate goods required in their production[2]. In this paper, we have illustrated using the example of automobile, analysis involving the retrospective accumulation method based on input-output analysis.

However, problems regarding the use of LCA remain. First, as we have used Japan's input-output table, CO_2 emission from the production and transport of raw materials and energy from abroad have not been included in the calculation. However, CO_2 emission effects induced abroad could be captured using the international input-output tables. Moreover, in this paper we have assumed that imports from abroad are produced using the same technology as that in Japan, while the transport of imports has been ignored in the study.

Second, we are still in the process of extending the input-output tables to include the effects of recycling and the absorption of CO_2 by plants.

The third point is that, we have also ignored the CO_2 emission induced from the production of manufacturing facilities. However, as seen in case of electricity, CO_2 emissions induced from the construction of manufacturing facilities are relatively small compared to that induced from production activities[3].

As the concept of LCA is based on the accumulation of all the burden which the products of individual firms exert on the environment. It is necessary to single out the effects each product exerts on the environment.

As the results of the input-output tables are available, there should be incentives to carry out detailed survey so as to differentiate the data contain in both. Further, with the information provided in the input-output table, they help to reduce the omissions that may occur in the accumulation process. Therefore, the introduction of input-output tables in LCA is important from both the point of view of calculation efficiency and comprehensive coverage.

[2] Yoshioka et al.(1992b)
[3] Yoshioka et al.(1994)

Nevertheless, there is a limit individual firm could claim about the burden its product exerts on the environment. For instance, even if the burden one's product exerts on the environment is small, but the reason behind being that electricity input is obtained from nuclear power instead of coal-fired power, then the evaluation will become rather difficult.

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