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# **Economic Performance, Greenhouse Gas Emissions, Environmental Management, and Supply Chains in India: A Comparison with Japan**

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Additional information is available at the end of the chapter

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## **Abstract**

Using input–output tables and data on wastes from the Japanese industrial sectors, we have provided empirical evidence that, in Japan environmental performance of their upstream suppliers contributes positively to the performance of their final product assembly firms or economic sectors. In this paper, we propose to investigate the same hypothesis for firms and other establishments in manufacturing and other sectors in India. Indian supplier firms that sell goods and services to their client assembler firms are not generally structured in the form of efficient supply chains as in advanced economies. So, the environmental performance of these suppliers may not have positive impacts on the performance of their assembler firms or economic sectors, but this is yet to be verified empirically.

In our study on Japan, we measured supply chains' environmental performance using various amounts of waste materials and also CO<sub>2</sub>-equivalent greenhouse gas emissions generated in their production processes. Unfortunately, the only environmental performance data we have for the Indian economic sectors is their CO<sub>2</sub> emissions. So, we investigate the impact of CO<sub>2</sub> emissions by supplier firms on the economic performance of their assembler firms in India.

**Keywords:** greenhouse gas emissions, supply chains, environmental management, firm performance, India

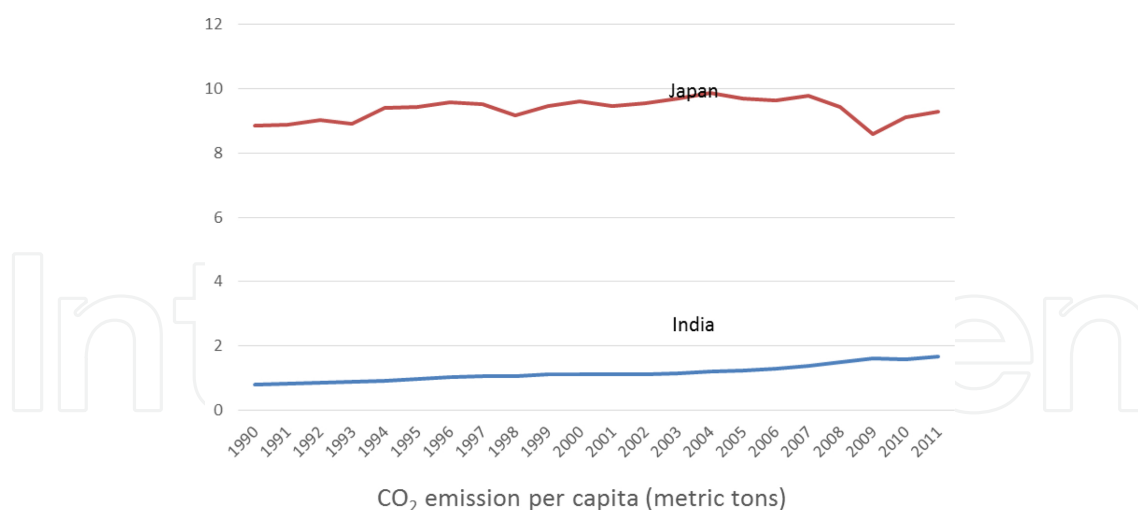
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## 1. Introduction

Limiting the amounts of industrial wastes generated in firms' manufacturing processes has been of policy interest in recent years. A type of waste of our interest in this paper is greenhouse gases (represented by the carbon dioxide equivalent below). Even though it is not harmful to human health, CO<sub>2</sub> is being regulated like toxic industrial wastes in many developed countries including Japan. More recently, the importance of limiting CO<sub>2</sub> emissions globally has been recognized by both developed and developing nations, and an international treaty to strengthen the former Kyoto protocol was signed in Paris.<sup>1</sup>

One of the topics of research interest, which has not received much empirical attention, is the extent to which CO<sub>2</sub> emissions, as an industrial waste, are generated along firms' supply chains. Although we see large corporations (e.g., 3M, Sony) promoting green procurement policies and claiming to use environment-friendly suppliers, we have little empirical evidence yet to suggest how such environmental management methods based on supply chains might benefit large downstream firms economically. We do not have much empirical evidence either about the impacts on final products of environmental management policies conducted by firms in their supply chains emerging in developing countries like India.

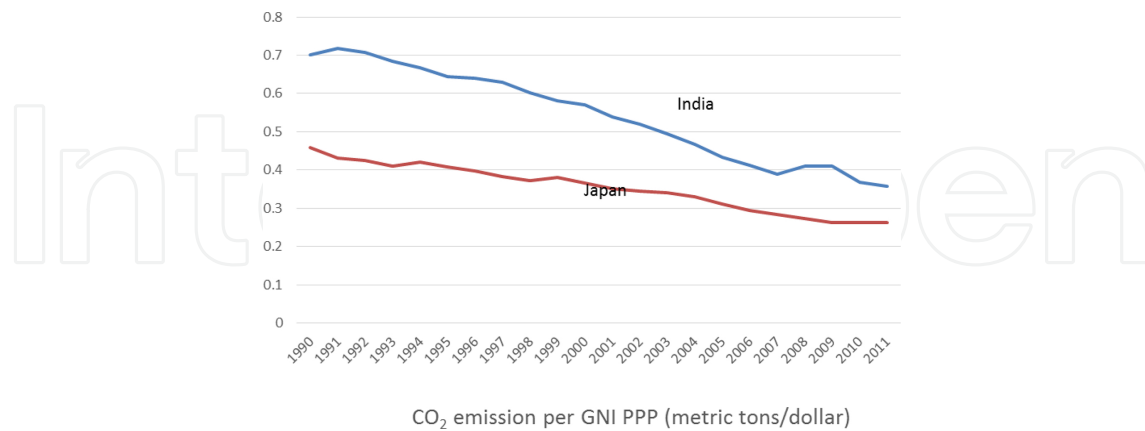
In this paper we present empirical estimates for the amounts of greenhouse gas (GHG) emissions generated by Indian manufacturing and other economic sectors, and their supply chains. (GHG emissions are measured in carbon dioxide (CO<sub>2</sub>) equivalent in this paper.) We then estimate their contributions to firm performance measured in terms of value added. **Figures 1 and 2** show CO<sub>2</sub> emissions per person and per income, respectively, in India and



**Figure 1.** CO<sub>2</sub> emissions per capita: India and Japan, 1990–2011. Source: Prepared by the authors using figures in [2–5].

<sup>1</sup> The 2015 United Nations Climate Change Conference, held in Paris, France, from November to December 2015 was the 21st yearly session of the Conference of the Parties (COP) to the 1992 United Nations Framework Convention on Climate Change (UNFCCC) and the 11th session of the Meeting of the Parties to the 1997 Kyoto Protocol. The Paris Agreement, a global agreement on the reduction of climate change, the text of which represented a consensus of the representatives of the 196 parties attending it, was signed. It needs to be ratified to become a world treaty [1].

Japan over time. We see from these figures that while Japan emits more CO<sub>2</sub> than India per capita, Japan generates less CO<sub>2</sub> emissions per dollar than India does.



**Figure 2.** CO<sub>2</sub> emissions per GNI (gross national income): India and Japan, 1990–2011. Source: Prepared by the authors using figures in [2–5].

The rest of the paper is organized as follows. After a brief review of earlier studies in Section 2, we discuss our method and approach toward the analysis of the generation of industrial waste (CO<sub>2</sub> emissions here) by supply chains in Section 3. Our data are briefly introduced in Section 4. We show and analyze certain patterns that are found in the generation of CO<sub>2</sub> emissions in Indian and Japanese industries in Sections 5 and 6. Section 6 presents our empirical results that relate the value added to the generation of wastes by downstream and upstream firms. Section 7 concludes.

## 2. Literature

There are relatively few research studies that use nations' input–output (I–O) tables as the data source for analyzing the relationships between supply chains and firms' environmental performance. Hayami et al. [6] present a framework in which I–O tables can be used for analyzing the effects, at the sector level, of the environmental management performance of firms in supply chains on their downstream assembly firms' performance. They present references on the literature that discusses many aspects of environmental management at upstream supply chains as related to their downstream customer firms [7,8]. Discussions on supply chains in India are also found [9–11]. Details of I–O analysis and applications to the Indian economy and environmental management are found in papers contained in [12].

## 3. Our approach to estimating output and waste along the stages of a supply chain

As noted earlier, certain downstream producers in developed countries are beginning to practice "green procurement," by which upstream suppliers with greener production proc-

esses become the preferred suppliers of their downstream customer firms. For example, Cisco, NEC, Sony, and Toshiba discuss their corporate green procurement guidelines in [13–16]. We apply this notion to India and investigate empirically the extent to which the same notion holds in India.

In order for the government to evaluate the potential benefits (i.e., the greening) of upstream firm production processes resulting from promoting downstream instruments, it is essential that we estimate relationships that describe the generation of waste materials at both upstream and downstream firms in a national economy. However, to our knowledge, only Hayami et al. present an empirical framework to achieve this objective using available data [6]. They also present an empirical model that allows us to estimate downstream firms' benefits of reduction of their suppliers' environmental wastes.

We apply the above model to India and derive some preliminary empirical estimates that evaluate the relative importance of the waste materials generated along the supply chain. Our findings in this chapter provide complementary evidence to the importance of environmental management in supply chains reported, for example, for individual firms, obtained using survey data and methodologies different from ours [8,17].<sup>2,3</sup>

### 3.1. Estimation of output along a supply chain

Our methodology is based on the input–output (I–O) analysis originally developed by Leontief [19,20]. (Applications of the I–O analysis to waste management and other environmental issues are found, for example, in [12,21–23]. Additional uses of input–output analysis in environmental management are found in [24]. We divide an economy into industrial and other economic sectors where production of goods and services takes place. We define I–O technical coefficients  $a_{ij}$  ( $i, j = 1, 2, \dots, n$ ) to be the amount of input from sector  $i$  per unit amount of output from sector  $j$ . To ensure positive output values, it is customary to assume the Hawkins–Simon condition [25] that  $a_{ij}$  lie between 0 and 1 and their column sums are less than 1.

Suppose  $x_j$  denotes the output from sector  $j$ . Then  $a_{ij}$  are estimated as follows:

$$a_{ij} = (X_{ij} / x_j),$$

where  $X_{ij}$  denotes the amount of input from sector  $i$  that is required for the production of  $x_j$ . Using supply chain terms, we say  $a_{ij}$  connect downstream output from sector  $j$  to its immediate predecessor upstream input from sector  $i$ .

We denote by  $A$  an  $n \times n$  matrix with elements  $a_{ij}$ , and by  $x$  an  $n \times 1$  vector in which each component  $x_j$  represents domestic production (output) of sector  $j$  ( $j = 1, 2, \dots, n$ ). We also denote

<sup>2</sup> A questionnaire-based survey across 124 companies from eight industrial sectors in Taiwan was used [17] in one study, while survey data on a sample of 122 firms drawn from electronics manufacturers listed on the database of the Taiwan Stock Exchange Corporation (TWSE) market and the Gre Tai Securities Market (GTSM) in Taiwan was used in another study [8].

<sup>3</sup> See [18] where Indian manufacturers' approaches to green supply chain management are explained.

by  $f_i$  the final downstream demand for sector  $i$ . We denote by  $f$  the corresponding  $n \times 1$  final downstream demand vector. For example,  $f_i = 1$  means a unit final downstream demand for output from sector  $i$ . (For simplicity, we ignore the impacts of international trade.)

In order to produce the final downstream demand  $f$ , the total amount of input required from sector  $i$  in the immediate predecessor stage (denoted by  $k = 1$ ) is given by

$$x^{(k=1)} = Af.$$

$x^{(1)}$  is also interpreted to be the indirect demand for the previous stage ( $k = 1$ ) production process, which is induced by final demand  $f$ , because without the production of  $x^{(1)}$ , the final demand cannot be met. In order to produce  $x^{(1)}$ , the total amount of input required from sector  $i$  in the immediate predecessor stage (denoted by  $k = 2$ ) in the supply chain is given by the  $i$ th element of the following vector:

$$x^{(2)} = Ax^{(1)} = A^2 f.$$

Generally, we can trace production activities along the supply chain backward, starting from the final demand, and we get

$$x^{(k)} = Ax^{(k-1)} = A^k f, k = 1, 2, \dots$$

We call  $x^{(k)}$  the  $k$ th stage indirect effect of final demand  $f$  ( $k = 1, 2, \dots$ ) in the supply chain.

In order to be able to produce final demand  $f$ , the following total indirect output must be produced:

$$x^{(indirect)} = Af + A^2 f + \dots + A^k f + \dots = A(I - A)^{-1} f,$$

where  $(I - A)^{-1}$  is the Leontief inverse matrix which exists provided that the  $a_{ij}$  satisfy the Hawkins–Simon condition given above.

We have shown that our input–output analysis identifies the successive upstream production processes that are followed by the average supply chain for the final demand vector  $f$ . This is summarized as follows. The input–output analysis describes all economic activities of the average supply chain in a national economy by following input–output transactions for all goods and services. The analysis typically starts from the final stage of downstream demand as shown above and moves backward by backtracking all predecessor upstream stages of production.

In this paper, we consider CO<sub>2</sub> (defined here to be the combined greenhouse gases measured in CO<sub>2</sub> equivalent) as a waste material associated with industrial production activities.

### 3.2. Graphical representation of connectedness of I–O sectors

Different sectors tend to be more connected in modern developed economies than in developing economies. This is because, in a modern economy, unproductive sectors will become more productive, with inputs from more productive sectors to survive. In addition, primary sectors and supplier sectors of manufacturing are connected to assembly sectors of manufacturing in a functional and efficient manner in supply chains. These functional connections are often missing in developing economies. **Figures 3–5** show the degrees of 35 I–O sectors' connectedness to each other in India and Japan. These 35 sectors are as follows:

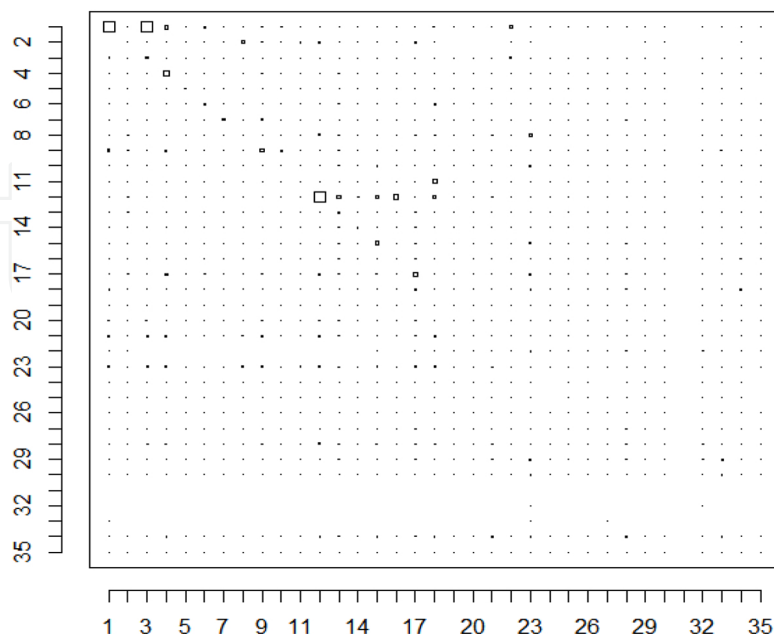
No.	Name
1	Agriculture, Hunting, Forestry, and Fishing
2	Mining and Quarrying
3	Food, Beverages, and Tobacco
4	Textiles and Textile Products
5	Leather and Footwear
6	Wood, and Products of Wood and Cork
7	Pulp, Paper, Printing, and Publishing
8	Coke, Refined Petroleum, and Nuclear Fuel
9	Chemicals and Chemical Products
10	Rubber and Plastics
11	Other Nonmetallic Minerals
12	Basic Metals and Fabricated Metals
13	Machinery, NEC
14	Electrical and Optical Equipment
15	Transport Equipment
16	Manufacturing, NEC; Recycling
17	Electricity, Gas, and Water Supply
18	Construction
19	Sales, Maintenance, and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel
20	Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles
21	Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods
22	Hotels and Restaurants
23	Inland Transport
24	Water Transport
25	Air Transport
26	Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies
27	Posts and Telecommunications
28	Financial Intermediation
29	Real Estate Activities
30	Renting of m&eq and Other Business Activities
31	Public Administration and Defense; Compulsory Social Security
32	Education
33	Health and Social Work
34	Other Community, Social, and Personal Services
35	Private Households with Employed Persons

Source: [5,32].

List of 35 aggregate I–O sectors used in **Figures 3–5**

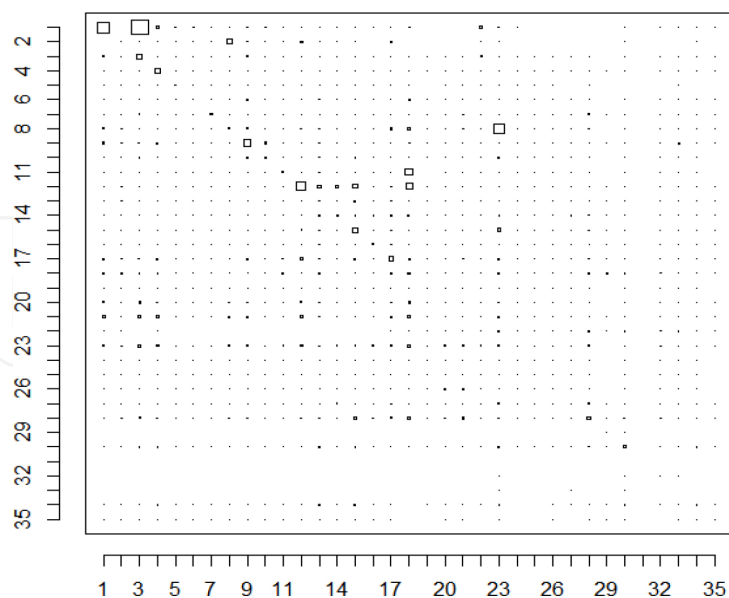


### Input-Output Table India, 1995



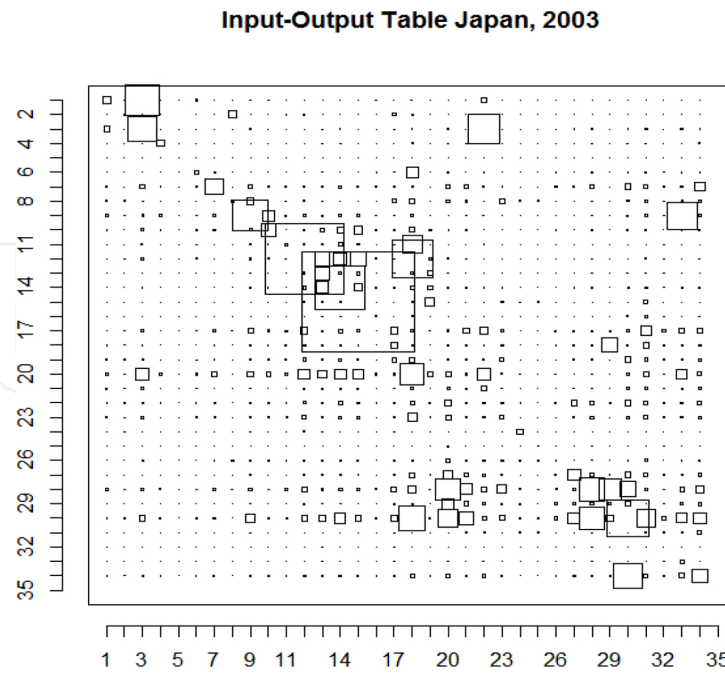
**Figure 3. Degrees of connectedness of 35 I-O sectors: India, 1995.** Note: The size of each square represents the amount of relevant input for the cell measured in terms of US \$million dollars at current price. Numbers on vertical and horizontal axes represent 35 I-O sectors for India and Japan defined in the text.

### Input-Output Table India, 2003



**Figure 4. Degrees of connectedness of 35 I-O sectors: India, 2003.** Note: The size of each square represents the amount of relevant input for the cell measured in terms of US \$million dollars at current price. Numbers on vertical and horizontal axes represent 35 I-O sectors for India and Japan defined in the text.





**Figure 5. Degrees of connectedness of 35 I-O sectors: Japan, 2003.** Note: The size of each square represents the amount of relevant input for the cell measured in terms of US \$million dollars at current price. Numbers on vertical and horizontal axes represent 35 I-O sectors for India and Japan defined in the text.

Intuitively speaking, **Figures 3–5** show the degrees of connectedness between sectors in terms of economic transactions. For example, sectors whose transactions are mostly within themselves are depicted as single dots. On the other hand, if two different sectors have more transactions with each other, then those two sectors are connected by a box. Multiple sectors with transactions, such as sectors that define supply chains, are shown with larger boxes containing them. As expected, **Figures 3 and 4** show that sectors of the Indian economy are not much connected to each other, though there are considerably more connectedness observed during 2003 than during 1995. This implies that there are increasingly more supply chain type relationships emerging in the Indian economy in recent years. The Japanese economy has developed well-defined supply chain based relationships among sectors in many industries [6]. This is clearly observed in **Figure 5**. We speculate from these figures, for example, that environmental management performance of upstream suppliers affect the performance of downstream firms much more in Japan than in India.

### 3.3. Estimation of wastes along a supply chain<sup>4</sup>

In the I–O analysis presented in Section 3.1, it is customary to include output which has economic value.<sup>5</sup> It is also customary to assume that industrial waste has no economic value in the form it is generated. For these reasons, industrial wastes are not included in our analysis

<sup>4</sup> Waste here denotes CO<sub>2</sub>, but our formulation applies to other waste materials as well.

<sup>5</sup> In reality, most waste materials have positive or negative economic value. For example, CO<sub>2</sub> has economic value in the GHG market currently [26].

in Section 3.1.<sup>6</sup> We treat waste materials separately here. Suppose we have estimated  $E1_j$ , the amount of waste generated per unit of output produced in sector  $j$  ( $j = 1, 2, \dots, n$ ). We denote by  $E$  the corresponding  $n \times n$  diagonal matrix with  $E1_j$  in the  $j$ th diagonal position. Then the amounts of waste produced by the output of sector  $j$  along the successive stages of a supply chain are given as follows:

Denote by  $w_j$  the amount of waste generated in sector  $j$ , and denote by  $w$  an  $n \times 1$  vector consisting of  $w_j$  ( $j = 1, 2, \dots, n$ ).

Then in the final stage, stage 0 ( $k=0$ ), of a supply chain, the demand is  $f$ , and the waste generated is

$w^{(0)} = EA^0f = Ef$ , which is the waste generated from assembly operations of final output  $f$ .

In the immediate predecessor upstream stage, stage 1 ( $k=1$ ), of the supply chain, the amount of waste generated (called indirect output for stage 1) is

$$w^{(1)} = EAx^{(0)} = EAf.$$

Similarly, we can derive the amount of waste generated along the upstream stages ( $k=2, 3, \dots$ ) of the supply chain as follows:

$$w^{(k)} = EAx^{(k-1)} = A^k f, k = 2, 3, \dots$$

This is shown in the last row of **Table 1**.

Upstream	Stages of a supply chain (→ → → closer to the final demand → → →)			Downstream: final stage of a supply chain (final demand)
Total indirect output and waste in upstream stages ( $k = 1, 2, \dots$ )	← ← ←	Indirect output for the $m$ -th stage in upstream ( $k = m$ )	← ← ← Indirect output for the second stage in upstream ( $k = 2$ )	Indirect output for the first stage in upstream ( $k = 1$ )
Production output along the stages of a supply chain				
$x^{(\text{indirect})} = Af + A^2f +$	← ← ←	$x^{(n)} = Ax^{(n-1)} = A^n f$	← ← ← $x^{(2)} = Ax^{(1)} = A^2f$	$x^{(1)} = Af$
				$f$ (direct output)

<sup>6</sup> Actual statistical treatment of industrial waste materials depends on the nature of each waste material, which we will not discuss here.

Upstream	Stages of a supply chain (→ → → closer to the final demand → → →)	Downstream: final stage of a supply chain (final demand)
$\dots + A^kf$ $+ \dots = A$ $(I - A)^{-1}f$ Waste output generated along the stages of a supply chain $w^{(\text{indirect})} =$ $A Ef + A^2 Ef$ $+ \dots + A^k Ef$ $+ \dots = A(I - A)^{-1} Ef$	$\leftarrow \leftarrow \leftarrow w^{(n)} = A^n E \leftarrow \leftarrow \leftarrow w^{(2)} = A^2 Ef$	$w^{(1)} = A Ef$ $Ef$ (direct waste generated)

Table 1. Production and waste output along the stages of a supply chain.

3.4. Output along a firm-specific supply chain and statistically obtained average output along the average supply chain

We do not have data on individual firm-specific supply chains that expand from downstream to upstream stages of production. However, element  $a_{ij}$  of input–output matrix  $A = \{a_{ij}, i, j = 1, 2, \dots, n\}$  is in fact the statistically estimated average fraction of output of sector  $i$  that goes to sector  $j$ . This statistical method of obtaining matrix  $A$  (called the commodity flow method) thus allocates input  $X_{ij}$  from the data of total output  $x_j$  [27], that is,  $a_{ij}$  connects downstream sector  $j$  to its immediate upstream sector  $i$  statistically. We have used this property of matrix  $A$  to obtain the average production and waste output along the stages of the average supply chain,  $x^{(k)}$  and  $w^{(k)}$ ,  $k = 1, 2, \dots$ , given downstream demand vector  $f$ . If we had data on production and waste output for the stages of all firm-specific supply chains for given  $f$ , then our I–O based estimates give the first-order approximation to the average output of the quantities for all such firm-specific supply chains. (The first-order approximation arises because of the linearity of  $a_{ij}$  which defines the I–O matrix  $A$ .)

4. Data

4.1. Input–output matrix

As we have noted in Section 3.1, our estimation methodology uses an  $n \times n$  matrix  $A$  consisting of

I–O technical coefficients  $a_{ij}$  ( $i, j = 1, 2, \dots, n$ ), where  $n$  is the number of economic sectors being considered. Since 1973, estimated values for  $a_{ij}$  ( $i, j = 1, 2, \dots, n$ ) are published every 5 years as I–O tables by the Government of India [9,28]. In this paper, we primarily use the Indian I–O tables for the years 1998–1999 and 2003–2004, with 130 sectors ( $n = 130$ ). The I–O sectors consist of 37 primary sectors, 68 secondary (manufacturing) sectors, and 25 service sectors.

In addition to the I–O matrix  $A = \{a_{ij} \ (i, j = 1, 2, \dots, n)\}$ , the Indian I–O table includes additional information on relevant economic quantities for each of the 130 sectors including final demand  $f$  for the Indian economy (see Appendix A1).

## 4.2. Waste and y-products surveys, and I–O matrix A

The environmental input–output table that we use here, based on greenhouse gas emission estimates (GOI, 2010), I–O table, material table, calorific table, combustion ratio table, and other data, was constructed by [9,12,29,30].

## 4.3. Calculating the amounts of waste materials

Using application of the input–output analysis described above, we used the estimated quantities of CO<sub>2</sub> for each of the 130 Indian I–O sectors, which we use in our regression analyses. We also used value-added estimations for each of these I–O sectors.

Using I–O analysis, we estimated the amounts of CO<sub>2</sub> generated per unit output for each of the 130 I–O sectors.

We are interested in studying the behavior of CO<sub>2</sub> emissions in firms' decision processes. In this paper, we denote by CO<sub>2</sub> emissions the total emissions in carbon dioxide equivalents of all greenhouse gases. CO<sub>2</sub> has certain characteristics in common in terms of their implications for firms' own economic incentives and government regulations.<sup>7</sup> For example, CO<sub>2</sub> emissions, like some other nontoxic wastes, are harmless to human health. On the other hand, CO<sub>2</sub> emissions, like some other waste materials, may also mean firms' excessive use of costly inputs (fossil fuels in case of CO<sub>2</sub>). (Note that CO<sub>2</sub> emissions and fossil energy use are highly correlated [32, 33].

# 5. Waste output along supply chains: example of an auto industry

One topic of research interest is to evaluate the relationships that might exist between downstream and upstream firms in terms of their waste behavior. Input–output analysis identifies statistically average economic relationships that exist between upstream and downstream firms. It is then possible to use input–output analysis also to find the average amounts of wastes that are generated by upstream firms in supply chains in response to production activities for the final products of downstream firms.

## 5.1. Example of an auto industry example

**Table 1** illustrates how our production of output and waste takes place along a supply chain starting from the final downstream demand. By tracing backward, final assembly plant

<sup>7</sup> In addition to direct regulations of various types pertinent to toxic wastes and CO<sub>2</sub>, indirect regulations often dictate firms' management of some of nontoxic wastes as well. For example, firms' nontoxic wastes are sometimes indirectly regulated in terms of the amounts of such waste materials that firms are allowed to bring to landfills and other waste processing facilities. Some nontoxic wastes have commercial value as well.

receives inputs from suppliers in upstream stage 1, who in turn receive their inputs from suppliers in upstream stage 2. As we have shown, I–O analysis allows us to estimate inputs between two successive stages of production along a supply chain.

5.2. A numerical example, India and Japan

This example illustrates the supply chain effects in the propagation of waste (CO<sub>2</sub>) generation along supply chains in India and Japan.

	Amounts generated (tons)	Cumulative amounts (tons)	Ratio to total
CO <sub>2</sub>			
Direct	0.107625	0.107625	0.020439
Indirect (first stage)	0.706568	0.814193	0.15462
Indirect (second stage)	1.205888	2.020081	0.383625
Indirect (third stage)	1.151894	3.171974	0.602376
Indirect (fourth stage)	0.896974	4.068948	0.772717
Total (all stages)	5.26577	5.265770	1

Source: Authors’ calculations.

**Table 2.** Supply chain effects, auto industry in Japan: CO<sub>2</sub> emissions generated by production of one passenger car with a 2000 cc engine.

	Amounts generated (tons)	Cumulative amounts (tons)	Ratio to total
CO <sub>2</sub>			
Direct	0.1346605	0.1346605	0.03002061
Indirect (first stage)	1.919879	2.054539	0.4580298
Indirect (second stage)	1.238733	3.293272	0.7341874
Indirect (third stage)	0.6406156	3.933888	0.8770033
Indirect (fourth stage)	0.3034687	4.237357	0.9446573
Total (all stages)	4.485602	4.485602	1

Source: Authors’ calculations.

**Table 3.** Supply chain effects, auto industry in India: CO<sub>2</sub> emissions generated by production of one passenger car with a 2000 cc equivalent engine.

**Tables 2 and 3** show how much CO<sub>2</sub> emissions occur along the auto supply chains in producing passenger cars with certain characteristics: median size cars in India and cars with 2000 cc engines in Japan.

We see from **Table 2** that firms along the auto supply chain in Japan generate 5.26577 tons of CO<sub>2</sub> emissions, but only 2% of this amount is generated by the final assembler firms. The remaining 98% of CO<sub>2</sub> emissions are generated by suppliers and other upstream firms in the supply chain. In comparison, the corresponding figures for India are: 4.485602 tons of total CO<sub>2</sub> emissions per car are generated in total, of which 3% is generated by the final assembler firms and the rest (97%) of the emissions are generated by suppliers (**Table 3**). This similarity in the patterns of CO<sub>2</sub> emissions along auto supply chains between India and Japan suggests that production technology of autos is reasonably standardized, perhaps due to the fact that many auto plants in India are owned and operated to a large extent by Western automakers. Another noteworthy point is that total CO<sub>2</sub> emissions per car produced is somewhat lower in India than in Japan. This difference occurs in part because of the sizes of passenger cars considered here that are different between India and Japan, and also in part because of the difference between India and Japan in the amounts of CO<sub>2</sub> emissions induced by imported car parts. The use of more imported parts implies lower levels of domestic CO<sub>2</sub> emissions, which is the case for India. For passenger car production, this ratio is 0.05846 for India and 0.02316 for Japan.

Based on the results given in **Tables 2 and 3**, we conclude that government environmental regulations about greenhouse gas emissions need to include not only the final auto producers but also many upstream suppliers, in order to be effective.

We noted that our results in **Tables 2 and 3** are consistent with the possibility that downstream firms might be able to upload the processing of CO<sub>2</sub> in particular to their upstream suppliers, while processing relatively large amounts of nonenergy-intensive tasks themselves in-house. This could easily happen in practice, since processing energy-intensive tasks is generally expensive.

We also note that this hierarchical structure of processing of the waste materials emitted by firms in assembly-based industries is likely to be typical. This is because of the nature of the types of assembly-based industries, which are most efficiently done by streamlining their supply chains so that assembly operations come last. In addition, assembly firms are generally more powerful than suppliers in their supply chains and hence have the most bargaining power.

Detailed processes of generation of CO<sub>2</sub> emissions by upstream and downstream firms are presented in **Tables 4 and 5**.

Auto CO <sub>2</sub>	Tons per passenger car (2000 cc equivalent)				
Direct	First indirect	Second indirect	3rd indirect	4th indirect	Total Generation
Passenger motor cars	0.1076 Electricity	0.1722 Electricity	0.5514 Electricity	0.3349 Pig iron	0.3230 Electricity 1.2862
	Motor vehicle parts and accessories	0.1013 Cast and forged materials (iron)	0.1115 Pig iron	0.1840 Electricity	0.1315 Pig iron 1.0449
	Internal combustion engines for motor vehicles and parts	0.0663 Road freight transport	0.0674 Private power generation	0.1040 Private power generation	0.1290 Private power generation 0.4804
	Private power generation	0.0603 Miscellaneous ceramic, stone, and clay products	0.0272 Coal products	0.0927 Coal products	0.0831 Coal products 0.3476
	Road freight transport	0.0599 Private power generation	0.0549 Self-transport by private cars (passengers) P	0.0393 Crude steel (converters)	0.0339 Road freight transport 0.1471
	Sheet glass and safety glass	0.0598 Nonferrous metal castings and forgings	0.0545 Crude steel (converters)	0.0287 Self-transport by private cars (passengers) P	0.0185 Cast and forged materials (iron) 0.1211
	Research and development (intra-enterprise)	0.0282 Self-transport by private cars (passengers) P	0.0268 Miscellaneous ceramic, stone and clay products	0.0268 Petroleum refinery products (inc. greases)	0.0162 Self-transport by private cars (passengers) P 0.1082
	Motor vehicle bodies	0.0280 Research and development (intra-enterprise)	0.0260 Hot rolled steel	0.0244 Paper	0.0144 Motor vehicle parts and accessories 0.1080
	Coastal and inland water transport	0.0165 Synthetic rubber	0.0225 Self-transport by private cars (freight) P	0.0225 Petrochemical basic products	0.0132 Passenger motor cars 0.1076
	Tires and inner tubes	0.0158 Hot rolled steel	0.0212 Road freight transport	0.0209 Hot rolled steel	0.0120 Crude steel (converters) 0.0910
	Plastic products	0.0114 Coated steel	0.0207 Cold finished steel	0.0202 Self-transport by private cars (freight) P	0.0107 Miscellaneous ceramic, stone and clay products 0.0895
	Waste management services (private)	0.0108 Thermoplastics resins	0.0190 Paper	0.0193 Road freight transport	0.0095 Petroleum refinery products (inc. greases) 0.0895
	Self-transport by private cars (passengers) P	0.0093 Cold finished steel	0.0158 Synthetic rubber	0.0166 Aliphatic intermediates	0.0089 Hot rolled steel 0.0689
	Cold finished steel	0.0093 Petroleum refinery products (inc. greases)	0.0154 Thermoplastics resins	0.0161 Miscellaneous ceramic, stone and clay products	0.0087 Internal combustion engines for motor vehicles and parts 0.0687
	Hot rolled steel	0.0076 Plastic products	0.0153 Petroleum refinery products (inc. greases)	0.0148 Coastal and inland water transport	0.0055 Research and development (intra-enterprise) 0.0638
	Miscellaneous ceramic, stone, and clay products	0.0071 Other rubber products	0.0131 Aliphatic intermediates	0.0135 Pulp	0.0051 Sheet glass and safety glass 0.0605
	Self-transport by private cars (freight) P	0.0049 Coastal and inland water transport	0.0129 Petrochemical basic products	0.0124 Cyclic intermediates	0.0048 Self-transport by private cars (freight) P 0.0597



Auto: CO <sub>2</sub>	Tons per passenger car (2000 cc equivalent)				
Direct	First indirect	Second indirect	Third indirect	Fourth indirect	Total generation
	Electrical equipment for internal combustion engines	0.0046Self-transport by private cars (freight) <i>P</i>	0.0128Coastal and inland water transport	0.0091Paperboard	0.0042Paper
	Electric bulbs	0.0044Coal products	0.0124Cast and forged materials (iron)	0.0080Waste management services (private)	0.0041Cold-finished steel
	Petroleum refinery products (inc. greases)	0.0037Cast and forged steel	0.0115Air transport	0.0071Cold-finished steel	0.0039Coastal and inland water transport
	Air transport	0.0032Other final chemical products	0.0104Waste management services (private)	0.0069Industrial soda chemicals	0.0036Synthetic rubber
	Abrasive	0.0030Wholesale trade	0.0100Research and development (intra-enterprise)	0.0065Crude steel (electric furnaces)	0.0035Thermoplastics resins
	Advertising services	0.0029Crude steel (converters)	0.0099Cyclic intermediates	0.0063Air transport	0.0031Nonferrous metal castings and forgings
	Other rubber products	0.0024Paper	0.0073Aluminum (inc. regenerated aluminum)	0.0062Ferro alloys	0.0031Petrochemical basic products
	Coated steel	0.0024Air transport	0.0066Other industrial organic chemicals	0.0050Cement	0.0029Aliphatic intermediates
	Wholesale trade	0.0023Motor vehicle parts and accessories	0.0061Other resins	0.0044Thermoplastics resins	0.0028Plastic products
	Harbor transport service	0.0023Steel pipes and tubes	0.0056Hired car and taxi transport	0.0038Petrochemical aromatic products (except synthetic resin)	0.0024Waste management services (private)
	Sewage disposal	0.0020Inorganic pigment	0.0053Coated steel	0.0037Synthetic rubber	0.0022Coated steel
	Hired car and taxi transport	0.0019Waste management services (private)	0.0050Industrial soda chemicals	0.0037Research and development (intra-enterprise)	0.0019Air transport
	Coal products	0.0018Electrical equipment for internal combustion engines	0.0050Crude steel (electric furnaces)	0.0036Other industrial organic chemicals	0.0018Motor vehicle bodies
30 sectors Subtotal	0.6983	1.1338	1.1338	1.0656	4.8655
Subtotal	0.1076	0.7066	1.2059	1.1519	5.2658
Cumulative	0.1076	0.8142	2.0201	3.1720	1.1968
Cumulative/Grand total	0.0204	0.1546	0.3836	0.6024	0.7727
					1.0000

**Table 4.** Generation of CO<sub>2</sub> by supply chains per production of a passenger car with a 2000 cc engine: Japan.

Auto: CO <sub>2</sub>	Tons per passenger car (2000 cc equivalent)				
Direct	First stage indirect	Second stage indirect	Third stage indirect	Fourth stage indirect	Total generation
Motor	0.1347 Electricity	0.8633 Electricity	0.7269 Electricity	0.4384 Electricity	0.2209 Electricity
Vehicles	Iron steel and ferroalloys	0.8470 Iron steel and ferroalloys	0.2832 Iron steel and ferroalloys	0.0799 Iron steel and ferroalloys	0.0266 Iron steel and ferroalloys
	Iron and steel casting and forging	0.0405 Petroleum products	0.0456 Petroleum products	0.0296 Petroleum products	0.0152 Motor vehicles
	Land transport including pipelines	0.0388 Nonferrous basic metals	0.0384 Nonferrous basic metals	0.0152 Cement	0.0063 Petroleum products
	Petroleum products	0.0205 Iron and steel casting and forging	0.0305 Land transport including pipelines	0.0126 Land transport including pipelines	0.0057 Iron and steel casting and forging
	Synthetic fibers and resin	0.0146 Land transport including pipelines	0.0254 Cement	0.0113 Nonferrous basic metals	0.0051 Land transport including pipelines
	Nonferrous basic metals	0.0141 Synthetic fibers and resin	0.0174 Iron and steel casting and forging	0.0109 Iron and steel casting and forging	0.0034 Nonferrous basic metals
	Motor vehicles	0.0125 Coal and lignite	0.0090 Synthetic fibers and resin	0.0072 Synthetic fibers and resin	0.0029 Synthetic fibers and resin
	Air transport	0.0119 Cement	0.0077 Coal and lignite	0.0050 Paper, paper products, and newsprint	0.0022 Cement
	Other nonmetallic mineral products	0.0071 Paper, paper products, and newsprint	0.0060 Paper, paper products, and newsprint	0.0041 Coal and lignite	0.0021 Paper, paper products, and newsprint
	Trade	0.0055 Railway transport services	0.0055 Inorganic heavy chemicals	0.0031 Inorganic heavy chemicals	0.0016 Coal and lignite
	Insurance	0.0046 Other nonmetallic mineral products	0.0052 Railway transport services	0.0031 Railway transport services	0.0014 Air transport
	Paper, paper products, and newsprint	0.0043 Inorganic heavy chemicals	0.0049 Natural gas	0.0025 Other nonmetallic mineral products	0.0012 Other nonmetallic mineral products
	Hand tools and hardware	0.0041 Natural gas	0.0045 Other nonmetallic mineral products	0.0024 Natural gas	0.0012 Railway transport services
	Railway transport services	0.0040 Trade	0.0037 Trade	0.0018 Other chemicals	0.0009 Inorganic heavy chemicals
	Rubber products	0.0040 Air transport	0.0036 Other chemicals	0.0017 Trade	0.0008 Trade
	Plastic products	0.0038 Coal products	0.0023 Air transport	0.0015 Fertilizers	0.0007 Natural gas
	Other chemicals	0.0034 Other chemicals	0.0021 Coal products	0.0013 Crude oil	0.0006 Other chemicals
	Banking	0.0033 Plastic products	0.0019 Crude oil	0.0010 Air transport	0.0006 Plastic products
	Inorganic heavy chemicals	0.0020 Motor vehicles	0.0014 Fertilizers	0.0009 Coal products	0.0005 Insurance
	Other transport equipment	0.0018 Banking	0.0013 Plastic products	0.0008 Plastic products	0.0003 Banking
	Other nonelectrical machinery	0.0017 Insurance	0.0013 Construction	0.0006 Construction	0.0003 Rubber products
	Miscellaneous metal products	0.0007 Construction	0.0010 Banking	0.0006 Banking	0.0002 Hand tools and hardware
	Art silk and synthetic fiber textiles	0.0006 Iron ore	0.0009 Insurance	0.0004 Structural clay products	0.0002 Coal products
	Communication	0.0006 Rubber products	0.0008 Structural clay products	0.0004 Insurance	0.0002 Fertilizers
	Coal and lignite	0.0005 Communication	0.0007 Water transport	0.0004 Water transport	0.0002 Crude oil
	Construction	0.0004 Hand tools and hardware	0.0006 Iron ore	0.0003 Other oil seeds	0.0002 Construction
	Electronic equipments including TV	0.0004 Water transport	0.0006 Communication	0.0003 Communication	0.0001 Other nonelectrical machinery
	Jute hemp and mesta textiles	0.0004 Miscellaneous manufacturing	0.0006 Storage and warehousing	0.0003 Storage and warehousing	0.0001 Other transport equipment
	Community, social, and personal services	0.0003 Miscellaneous metal products	0.0005 Rubber products	0.0003 Jute hemp and mesta textiles	0.0001 Communication
30 sectors subtotal	0.1347	1.9167	1.2333	0.6376	4.4656
Subtotal	0.1347	1.9199	1.2387	0.6406	4.4856
Cumulative	0.1347	2.0545	3.2933	3.9339	4.4856
Cumulative/Grand total	0.0300	0.4580	0.7342	0.8770	0.9447
					1.0000

Source: Authors' calculations.

**Table 5.** Generation of CO<sub>2</sub> by supply chains per production of a passenger car with a medium size engine: India.

**Tables 4 and 5** show the amounts of CO<sub>2</sub> emissions generated by the final auto producers, as well as their suppliers and other upstream firms, in producing a passenger car with a 2000 cc engine. These tables provide details on the amounts of waste materials generated by each of the industrial sectors, based on which figures reported in **Tables 2 and 3** were obtained.

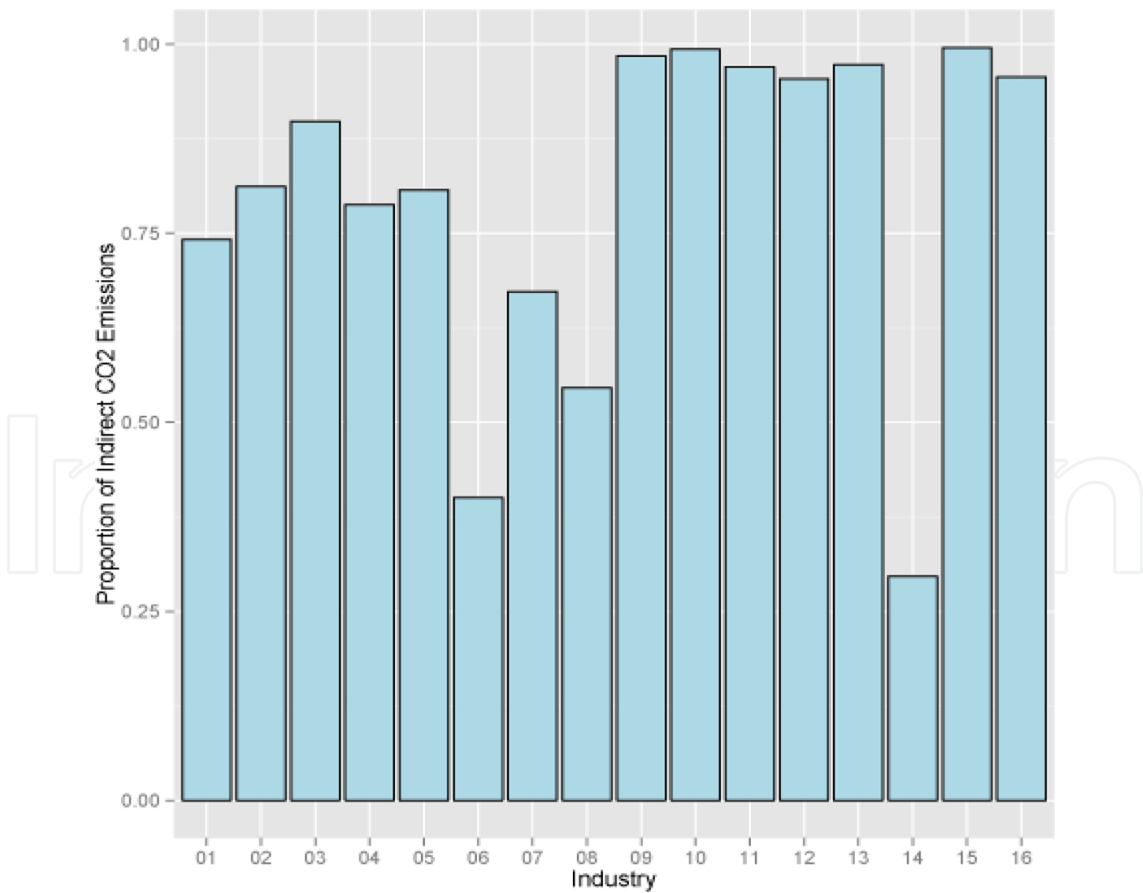


## 6. Estimating the contributions of direct and indirect CO<sub>2</sub> emissions

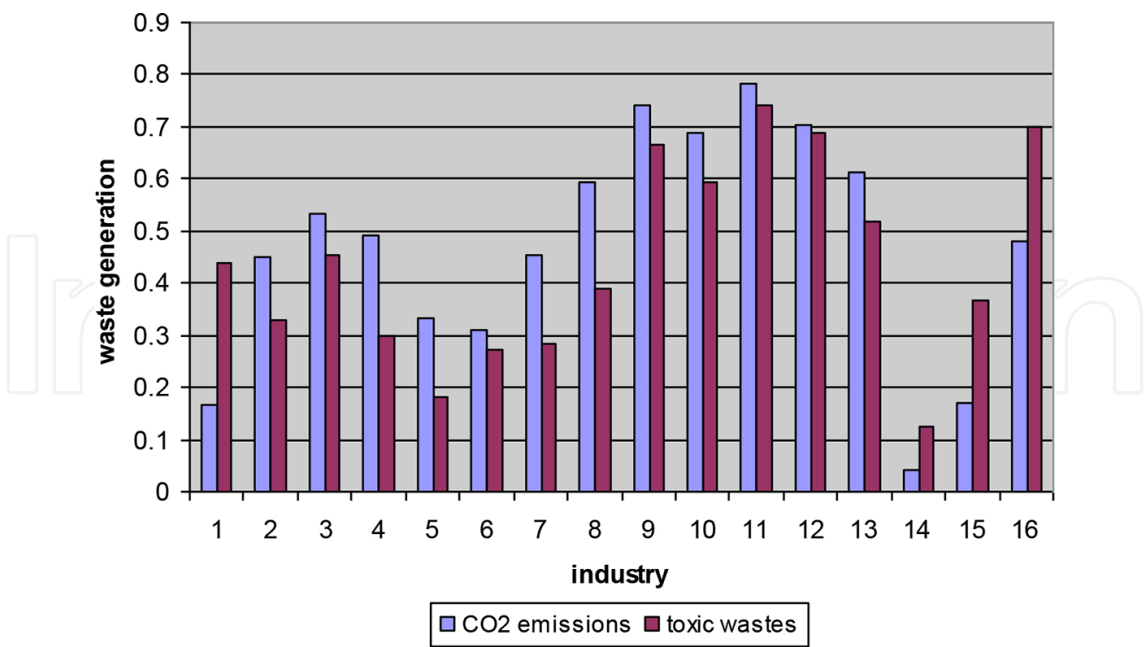
### 6.1. Relative contributions of direct and indirect CO<sub>2</sub> emissions to the total sectorial emissions

It is intuitively clear that final output (called output from downstream sectors), whether assembled manufactured products, or output from primary sectors such as mining and agriculture, uses much output produced in their predecessor sectors including suppliers (upstream sectors). It is then likely that the total emissions attributable to any final product (e.g., a passenger car) consist of significant amounts of indirect emissions from upstream sectors and direct emissions which are emitted from the final car assembly stage in the downstream part of the supply chains. **Figures 6** and **7** show the breakdown of direct and indirect emissions for 16 sectors. Industries 9–13 with asterisks are thought to be assembly-based manufacturing industries.

We see in these figures that CO<sub>2</sub> emissions are skewed toward upstream firms in manufacturing supply chains. This is particularly evident for Japan (**Figure 7**). **Figure 7** also shows that proportions of toxic wastes show a similar pattern.



**Figure 6.** CO<sub>2</sub> emissions by industry: proportions of indirect emissions for India.



**Figure 7.** CO<sub>2</sub> emissions by industry: proportions of indirect emissions for Japan. Notes: In this graph for Japan, proportions of indirectly generated amounts of toxic waste (solid and liquid) materials other than CO<sub>2</sub> are also shown.

1	Mining
2	Food production
3	Textiles
4	Pulp/paper
5	Chemicals
6	Petrol/Coal production
7	Basic metals
8	Nonferrous metals production
9*	General machinery
10*	Electric machinery
11*	Auto
12*	Transportation machinery
13*	Precision machinery
14	Electric power
15	Public utility
16	Service

\*Assembly-based manufacturing industries.

List of industries used in **Figures 6** and **7**

Are the patterns of CO<sub>2</sub> emissions across upstream and downstream economic sectors that we observed in **Figures 6** and **7** consistent with downstream firms' profit maximization behavior? We are interested in testing the following hypothesis:

H1: Downstream firms' performance (measured by their value added) is affected by their upstream firms' CO<sub>2</sub> emissions as well as their own.

In general, we expect upstream firms' generation of toxic wastes such as CO<sub>2</sub> to be a negative factor in firms' value added, but generation of nontoxic wastes may not be, since most nontoxic wastes have commercial value. We first focus on the impacts of downstream firms' immediate predecessor upstream firms on downstream firm performance, because the impacts, if any, of downstream firms' environmental management policies such as green procurement can extend most effectively to their immediate predecessor upstream suppliers.

	A	B	C	D
	India		Japan	
Dependent variable	Value added	Value added	Value added	Value added
Constant	0.5213*** (0.0415)	0.6965*** (0.0578)	0.4640*** (0.0099)	0.5087*** (0.0204)
Direct CO <sub>2</sub> waste (downstream)	-0.0043 (0.0034)	0.0649** (0.0194)	-0.0018* (0.0011)	-0.0016 (0.0011)
Indirect CO <sub>2</sub> waste (upstream total, all stages)	–	-0.1266*** (0.0347)	–	-0.0150** (0.0070)
Indirect CO <sub>2</sub> waste (upstream, first stage)	-0.0107*** (0.0115)	–	-0.0115*** (0.0030)	–
Adjusted R <sup>2</sup>	0.01846	0.27258	0.04373	0.12097
No. of observations	130	130	396	396

\*Significance level at 10%.

\*\*Significance level at 5%.

\*\*\*Significance level 1%.

Notes: The dependent variable (value-added) is measured per sector output.

Neither Harisson-McCabe nor Breusch-Pagan tests for heteroskedasticity detected statistically significant level in the regressions reported above.

We have also run regressions with log of value-added as the dependent variable. We obtained estimation results which are qualitatively the same. Further, we experienced considerable multicollinearity when indirect emissions from both first and all stages entered regressions. Therefore, we only report regressions with either one of the indirect emission variables here.

These regression results were calculated by the authors. Results for Japan in columns E and F are also reported in [6].

**Table 6.** Determinants of downstream firms' value added: effects of direct and indirect CO<sub>2</sub> emissions by upstream firms, India and Japan.

We test this hypothesis empirically by estimating the following regressions using a sample of economic sectors corresponding to Indian input-output sectors for which usable data are

available. The data used includes value added and the amounts of CO<sub>2</sub> emissions generated during direct and indirect stages of production for each of the input–output sectors in the sample. (Descriptive statistics for these variables for India and Japan are presented in Appendix 2.)

In our specification, we regress value added on the amounts of CO<sub>2</sub> generated directly by downstream firms as well as the amounts of CO<sub>2</sub> generated indirectly by their upstream producers. Our OLS regression results for India are given in columns A and B of Table 6. Columns C and D show the corresponding results for Japan.<sup>8</sup>

Even though CO<sub>2</sub> is not thought to be one of the industrial wastes in a traditional sense, the amounts of CO<sub>2</sub> emissions represent the levels of firms' inputs of fossil fuels. As such, like some other toxic wastes, firms have economic incentives, even without government regulations, to reduce such emissions of CO<sub>2</sub>, since the cost of energy can be a significant portion of firms' production costs. Furthermore, from policy perspectives, some policies introduced by the governments of developed countries have been promoting energy-efficient production processes for many years (e.g., beginning in the late 1970s, after the second oil crisis in Japan). And also, in recent years, CO<sub>2</sub> emission quota policies of various sorts are being introduced in Japanese, EU, and other nations' industries.

From Column C of Table 6, we see that 1 ton of direct waste output of CO<sub>2</sub> contributes to −0.0018 of firms' value added per yen of firms' output. On the other hand, contribution to firms' value added of the indirect waste output of CO<sub>2</sub> from their immediate upstream predecessor suppliers is −0.0115, which is numerically much larger and statistically more significant than our direct waste output. We conclude that firms face significant financial losses, measured by value added, when direct and indirect generation of CO<sub>2</sub> occurs in their own production processes. Generation of CO<sub>2</sub> emissions by firms' immediate upstream predecessor suppliers seems to have much larger negative effects on their value added than their own direct waste output. This suggests that downstream firms may have economic incentives to reduce waste output by their immediate predecessor upstream suppliers.

Comparing columns A (India) and C (Japan), we see similar patterns on how CO<sub>2</sub> emissions along supply chains affect final sectors' value added. As far as final sectors' direct emissions are concerned, direct CO<sub>2</sub> emissions have no impact on value added for India, since its coefficient (−0.0043) is statistically not significant. On the other hand, their immediate predecessor CO<sub>2</sub> emissions negatively affect final sectors' value added (with statistically significant coefficient (−0.0107)). But direct emission coefficients in Column B are positive and statistically significant (0.0649), suggesting that the more fossil energy is used by the final sector, the more productive (in terms of value added) final sectors become. This might indicate inefficient use of fossil energy, but this is not clear, since the same coefficient in column A is statistically insignificant.<sup>9</sup> In all cases, indirect emissions from all supplier stages combined are statistically

<sup>8</sup> Various tests of heteroskedasticity and specification tests that we have done, respectively, show little heteroskedasticity and little specification errors.

<sup>9</sup> We speculate that there are multiple channels through which downstream and upstream firms' environmental policies affect downstream firms' value added.

significant and negative. From these results, we tentatively conclude that, for India, environmental management policies encouraging suppliers in supply chains to reduce their CO<sub>2</sub> emissions will likely improve final sector firms' performance measured in terms of value added. These results for India are consistent with but are not as strong as the policy conclusions obtained for Japan [6].

## 7. Concluding remarks

Recent advances in supply chain based management methods have made it possible for many firms to organize their production and other business activities as part of the supply chains they belong to. Efficiency gains are realized in terms of reduced inventories, reduced lead times for new product development, and shorter delivery lags, among many other benefits. Our results suggest that including certain supply chain level environmental management schemes, such as "how to manage toxic and nontoxic wastes, as well as CO<sub>2</sub> emission for a supply chain as a whole," in such supply chain management methods might improve not only downstream firms' economic performance but also advanced economies' environmental performance significantly.

Consideration of such schemes may underlie some firms' proposals for green procurement policies. In many sectors of an advanced economy, as supply chain management becomes more sophisticated in pursuing economic efficiency, larger downstream firms tend to become more dominant as the primary driver of management decisions associated with their supply chains. (Note, however, that this phenomenon is not limited to assembly-based manufacturing industries. In retail industries, Walmart and the like have become the primary decision makers for their entire global supply chains.) It is possible that, as a national economy develops and increases its sophistication in logistic capabilities, organic connections between upstream and downstream firms become more prevalent, as we see in Japan. This might make it easier for some downstream firms to adopt green procurement policies.

Another factor that might be important to consider in supply chain based environmental policies is firm ownership structures. Ownership structures of firms involved in supply chains are complex but tend to share some systematic patterns. Dominant downstream firms generally influence business decisions of their upstream suppliers via some forms of partial ownership and/or certain guaranteed purchase agreements. Dominant firms do not necessarily extend their partial ownership to all other firms in their supply chains, but, nevertheless, dominant firms often have significant influence over smaller upstream firms through various sorts of business relationships.

Current public policies on waste management in Japan focus on firms and/or establishments. Because of the reasons stated above, this is not appropriate for an advanced economy in which many firm decisions are made at their supply chain levels in interrelated ways. Our empirical results present limited evidence, for both India and Japan, that downstream firms' economic performance is affected not only by their own environmental policies but also by the environmental behavior of their upstream suppliers. Some profit-maximizing firms may see

it to their advantage to implement green procurement policies. As we have shown, improving suppliers’ environmental performance may lead to immediate improvements in downstream firms’ economic performance. We suppose that government environmental policies need to accommodate this supply chain effect as well. As of now, few environmental regulations for downstream firms have serious implications for upstream firms’ environmental behavior.

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Appendix A1. 130 Sectors of the input–output Table: India, 2003

Code	Name	Code	Name
1	Paddy	41	Edible oils other than vanaspati
2	Wheat	42	Tea and coffee processing
3	Jowar	43	Miscellaneous food products
4	Bajra	44	Beverages
5	Maize	45	Tobacco products
6	Gram	46	Khadi and cotton textiles in handlooms
7	Pulses	47	Cotton textiles
8	Sugarcane	48	Woolen textiles
9	Groundnut	49	Silk textiles
10	Coconut	50	Art silk and synthetic fiber textiles

11	Other oil seeds	51	Jute hemp and mesta textiles
12	Jute	52	Carpet weaving
13	Cotton	53	Ready-made garments
14	Tea	54	Miscellaneous textile products
15	Coffee	55	Furniture and fixtures (wooden)
16	Rubber	56	Wood and wood products
17	Tobacco	57	Paper, paper products, and newsprint
18	Fruits	58	Printing and publishing
19	Vegetables	59	Leather footwear
20	Other crops	60	Leather and leather products
21	Milk and milk products	61	Rubber products
22	Animal services (agricultural)	62	Plastic products
23	Poultry and eggs	63	Petroleum products
24	Other livestock products	64	Coal products
25	Forestry and logging	65	Inorganic heavy chemicals
26	Fishing	66	Organic heavy chemicals
27	Coal and lignite	67	Fertilizers
28	Natural gas	68	Pesticides



29	Crude oil	69	Paints, varnishes, and lacquers
30	Iron ore	70	Drugs and medicines
31	Manganese ore	71	Soaps, cosmetics, and glycerin
32	Bauxite	72	Synthetic fibers and resin
33	Copper ore	73	Other chemicals
34	Other metallic minerals	74	Structural clay products
35	Limestone	75	Cement
36	Mica	76	Other nonmetallic mineral products
37	Other nonmetallic minerals	77	Iron, steel, and ferroalloys
38	Sugar	78	Iron and steel casting and forging
39	Khandsari and boora	79	Iron and steel foundries
40	Hydrogenated oil (vanaspati)	80	Nonferrous basic metals
<b>Code</b>	<b>Name</b>	<b>Code</b>	<b>Name</b>
81	Hand tools and hardware	116	Trade
82	Miscellaneous metal products	117	Hotels and restaurants

83	Tractors and agricul tural implements	118	Banking
84	Industrial machinery for food and textiles	119	Insurance
85	Other industrial machinery	120	Ownership of dwellings
86	Machine tools	121	Education and research
87	Other nonel ectrical machinery	122	Medical and health
88	Electrical industrial machinery	123	Business services
89	Electrical cables and wires	124	Computer-related services
90	Batteries	125	Legal services
91	Electrical appliances	126	Real estate
92	Communication equipment	127	Renting of machinery and equipment
93	Other electrical machinery	128	Community, social, and personal services
94	Electronic equipments including TV	129	Other services
95	Ships	130	Public administration

	and boats		and defense
96	Rail equipment	121	Education and research
97	Motor vehicles	122	Medical and health
98	Motor cycles and scooters	123	Business services
99	Bicycles and cycle-rickshaw	124	Computer-related services
100	Other transport equipment	125	Legal services
101	Watches and clocks	126	Real estate
102	Medical precision and optical instruments	127	Renting of machinery and equipment
103	Gems and jewelry	128	Community, social, and personal services
104	Aircraft and spacecrafts	129	Other services
105	Miscellaneous manufacturing	130	Public administration and defense
106	Construction	121	Education and research
107	Electricity	122	Medical and health
108	Water supply	123	Business services
109	Railway transport services	124	Computer-related services
110	Land	125	Legal services

	transport including pipelines		
111	Water transport	126	Real estate
112	Air transport	127	Renting of machinery and equipment
113	Supportive and auxiliary transport activities	128	Community, social, and personal services
114	Storage and warehousing	129	Other services
115	Communication	130	Public administration and defense

**Final Demand**

PFCE	Private final consumption expenditure
GFCE	Government final consumption expenditure
GFCF	Gross fixed capital formation
CIS	Changes in stocks
EXP	Exports
IMP	Imports
COMOUT	Domestic output (product)
VA	Value added
NIT	Net

	indirect
	tax
GVA	Gross
	value
	added
INDOUT	Domestic
	output
	(industry)

Source: [28,31].

Appendix A2. Descriptive statistics for regression variables: India, 2003 and Japan, 2000

India						
Variables	Mean	Std. dev.	Median	Minimum	Maximum	No. obs.
Value added (dep. variable)	0.47978	0.23504	0.38890	0.00908	1	130
GHG emissions (CO <sub>2</sub> equivalent): India, ton-CO <sub>2</sub> per million Rupees						
Direct emissions (from current sector)	1.4699	5.4709	0.1885	0.0000	48.1495	130
Indirect emissions (emissions from all previous sectors/stages combined)	2.4667	3.2255	1.9813	0.0000	27.4213	130
Indirect emissions (emissions from immediate predecessor sector/stage)	3.2817	2.5990	2.9807	0.0000	18.5870	130
Japan						
Variables	Mean	Std.dev.	Median	Minimum	Maximum	No. obs.
Value added (dep. var.)	0.444286	0.180905	0.408066	0	0.929868	396
GHG emissions (CO <sub>2</sub> equivalent): Japan, ton-CO <sub>2</sub> per million Yen						
Direct emissions (from current sector)	1.81488	8.02313	0.24814	0	104.2946	396
Indirect emissions (emissions from all previous sectors/stages combined)	2.99029	3.99268	1.98527	0	52.4515	396
Indirect emissions (emissions from immediate predecessor sector/stage)	1.42372	2.99584	0.71593	0	44.9873	396

Source: India—The dataset is compiled by the authors using *The Central Statistical Organisation, India* at current million Indian Rupees [28]. Japan—The dataset is compiled by the authors using data available from <http://www.stat.go.jp/english/data/io/index.htm> and Ministry of Economy, Trade and Industry.

Notes. Value added and direct waste outputs are measured per sector output. Indirect waste output for each stage is measured per total indirect output (all stages combined).

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