Chapter 1

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_2-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_2 emissions. So, we investigate the impact of CO_2 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

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_2 is being regulated like toxic industrial wastes in many developed countries including Japan. More recently, the importance of limiting CO_2 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.[1]

One of the topics of research interest, which has not received much empirical attention, is the extent to which CO_2 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_2) equivalent in this paper.) We then estimate their contributions to firm performance measured in terms of value added. **Figures 1** and **2** show CO_2 emissions per person and per income, respectively, in India and

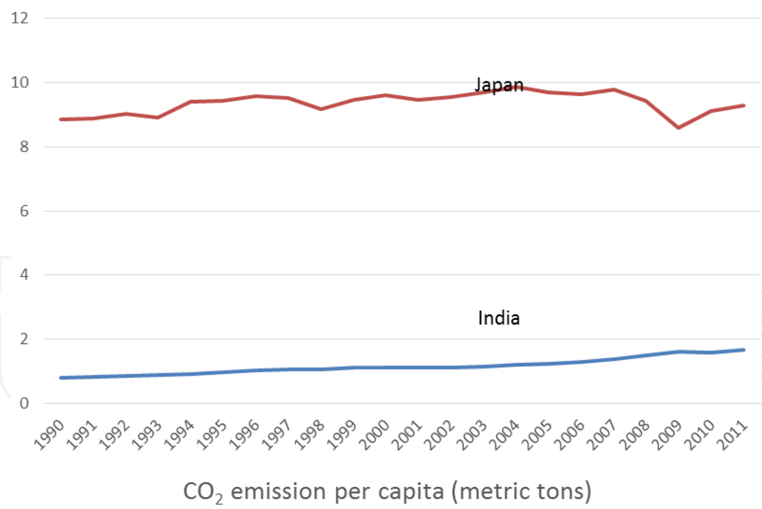

Figure 1. CO_2 emissions per capita: India and Japan, 1990–2011. Source: Prepared by the authors using figures in [2–5].

[1] 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_2 than India per capita, Japan generates less CO_2 emissions per dollar than India does.

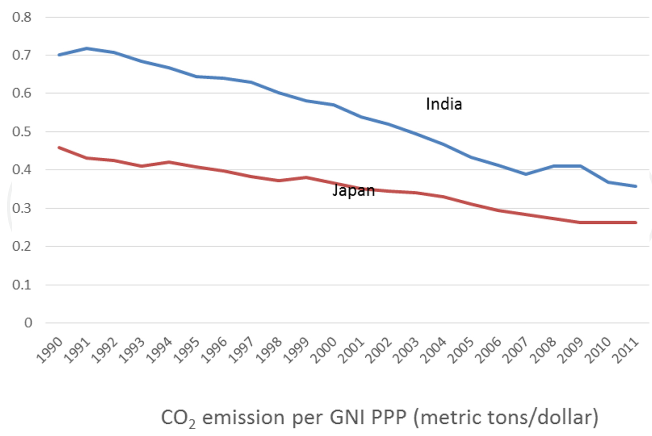

Figure 2. CO_2 emissions per GNI (gross national income): India and Japan, 1990–2011. Source: Prepared by the authors using figures in [2–5].

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_2 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_2 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 processes 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].[2],[3]

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} $(i,j = 1,2,\ldots,n)$ 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:

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

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 $(j = 1,2,..,n)$. We also denote

[2] 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].

[3] 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 ith 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

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

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

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

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

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_2 (defined here to be the combined greenhouse gases measured in CO_2 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**

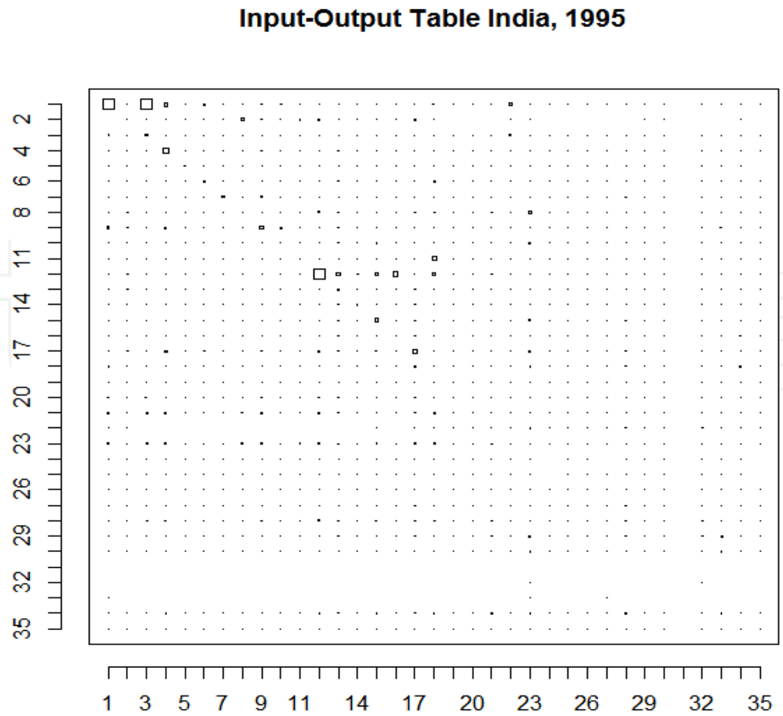

Figure 3. Degrees of connectedness of 35 I–O sectors: India, 1995. Note: The size of each square represents the amount of relevant input for the cell measured in terms of US $million dollars at current price. Numbers on vertical and horizontal axes represent 35 I–O sectors for India and Japan defined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

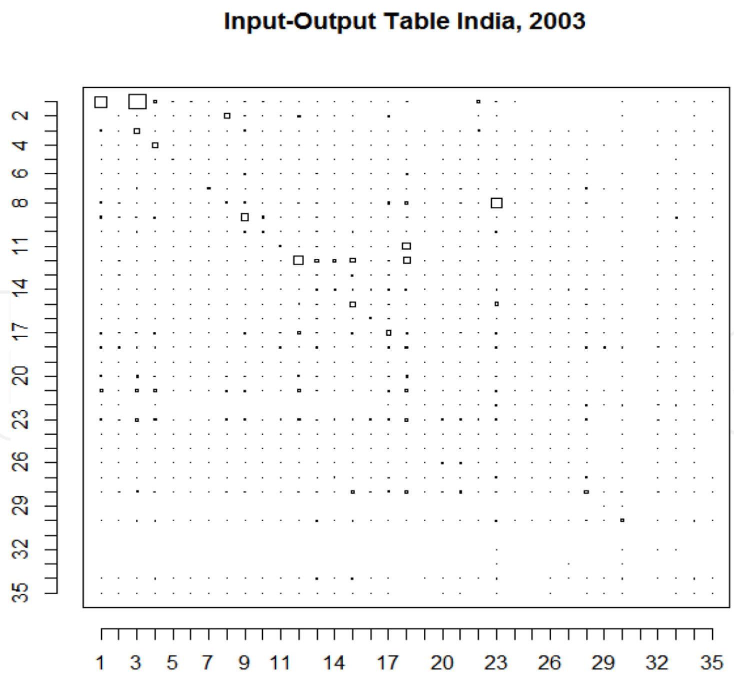

Figure 4. Degrees of connectedness of 35 I–O sectors: India, 2003. Note: The size of each square represents the amount of relevant input for the cell measured in terms of US $million dollars at current price. Numbers on vertical and horizontal axes represent 35 I–O sectors for India and Japan defined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

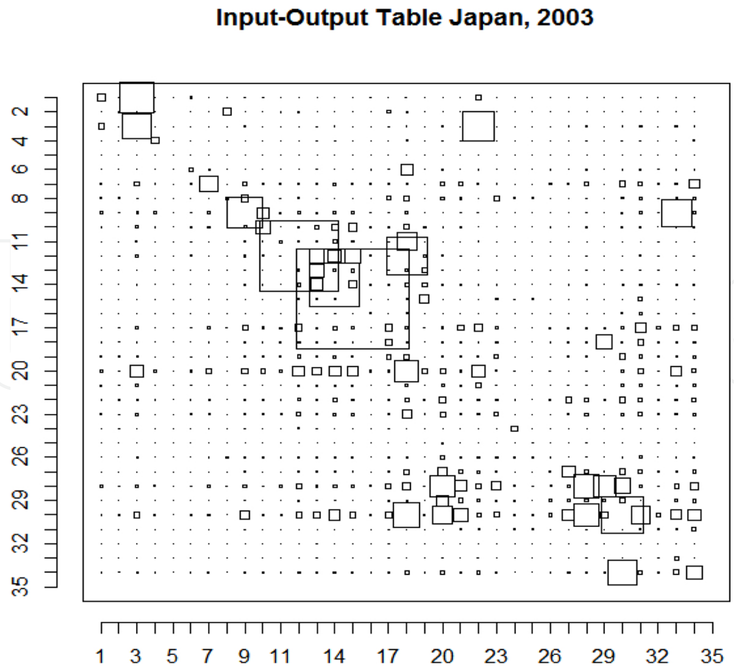

Figure 5. Degrees of connectedness of 35 I–O sectors: Japan, 2003. Note: The size of each square represents the amount of relevant input for the cell measured in terms of US $million dollars at current price. Numbers on vertical and horizontal axes represent 35 I–O sectors for India and Japan defined 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[4]

In the I–O analysis presented in Section 3.1, it is customary to include output which has economic value.[5] 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

[4] Waste here denotes CO_2, but our formulation applies to other waste materials as well.

[5] In reality, most waste materials have positive or negative economic value. For example, CO_2 has economic value in the GHG market currently [26].

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in Section 3.1.[6] 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,..,n). We denote by E the corresponding $n \times n$ diagonal matrix with $E1_j$ in the jth 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,..,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, …,) of the supply chain as follows:

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

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,…)	← ← ←	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						
$x^{(\text{indirect})} = Af + A^2f +$	← ← ←	$x^{(n)} = Ax^{(n-1)} = A^nf$	← ← ←	$x^{(2)} = Ax^{(1)} = A^2f$	$x^{(1)} = Af$	f (direct output)

[6] 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)
$\ldots + A^k f + \ldots = A(I - A)^{-1} f$						
Waste output generated along the stages of a supply chain						
$w^{(\text{indirect})} = AEf + A^2Ef + \ldots. + A^kEf + \ldots = A(I - A)^{-1}Ef$	← ← ←	$w^{(n)} = A^nE$	← ← ←	$w^{(2)} = A^2Ef$	$w^{(1)} = AEf$	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 $A = \{a_{ij}, i, j = 1,2,..,n\}$ 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 $w^{(k)}$, $k = 1,2,\ldots$, 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} $(i,j = 1,2,\ldots,n)$, where n is the number of economic sectors being considered. Since 1973, estimated values for a_{ij} $(i,j = 1,2,\ldots,n)$ 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 $A = \{a_{ij}\ (i,j = 1,2,\ldots,n)\}$, 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_2 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_2 generated per unit output for each of the 130 I–O sectors.

We are interested in studying the behavior of CO_2 emissions in firms' decision processes. In this paper, we denote by CO_2 emissions the total emissions in carbon dioxide equivalents of all greenhouse gases. CO_2 has certain characteristics in common in terms of their implications for firms' own economic incentives and government regulations.[7] For example, CO_2 emissions, like some other nontoxic wastes, are harmless to human health. On the other hand, CO_2 emissions, like some other waste materials, may also mean firms' excessive use of costly inputs (fossil fuels in case of CO_2). (Note that CO_2 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

[7] In addition to direct regulations of various types pertinent to toxic wastes and CO_2, 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_2) generation along supply chains in India and Japan.

	Amounts generated (tons)	Cumulative amounts (tons)	Ratio to total
	CO_2		
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_2 emissions generated by production of one passenger car with a 2000 cc engine.

	Amounts generated (tons)	Cumulative amounts (tons)	Ratio to total
	CO_2		
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_2 emissions generated by production of one passenger car with a 2000 cc equivalent engine.

Tables 2 and **3** show how much CO_2 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_2 emissions, but only 2% of this amount is generated by the final assembler firms. The remaining 98% of CO_2 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_2 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_2 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_2 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_2 emissions induced by imported car parts. The use of more imported parts implies lower levels of domestic CO_2 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_2 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_2 emissions by upstream and downstream firms are presented in **Tables 4** and **5**.

Auto: CO_2	**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	1.2982
		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	0.0474	Private power generation	0.1040	Private power generation	0.1290	Private power generation	0.4804
		Private power generation	0.0601	Miscellaneous ceramic, stone, and clay products	0.0372	Coal products	0.0927	Coal products	0.0831	Coal products	0.3476
		Road freight transport	0.0599	Private power generation	0.0349	Self-transport by private cars (passengers) P	0.0393	Crude steel (converters)	0.0319	Road freight transport	0.1471
		Sheet glass and safety glass	0.0598	Nonferrous metal castings and forgings	0.0345	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	0.0209	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)	0.0106	Thermoplastics resins	0.0190	Paper	0.0193	Road freight transport	0.0095	Petroleum refinery products (inc. greases)	0.0695
		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	Petroleumrefinery 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_2		Tons per passenger car (2000 cc equivalent)									
Direct		First indirect		Second indirect		Third indirect		Fourth indirect		Total generation	
		Electrical equipment for internal combustion engines	0.0046	Self-transport by private cars (freight) *P*	0.0128	Coastal and inland water transport	0.0091	Paperboard	0.0042	Paper	0.0537
		Electric bulbs	0.0044	Coal products	0.0124	Cast and forged materials (iron)	0.0080	Waste management services (private)	0.0041	Cold-finished steel	0.0509
		Petroleum refinery products (inc. greases)	0.0037	Cast and forged steel	0.0115	Air transport	0.0071	Cold-finished steel	0.0039	Coastal and inland water transport	0.0499
		Air transport	0.0032	Other final chemical products	0.0104	Waste management services (private)	0.0069	Industrial soda chemicals	0.0036	Synthetic rubber	0.0424
		Abrasive	0.0030	Wholesale trade	0.0100	Research and development (intra-enterprise)	0.0065	Crude steel (electric furnaces)	0.0035	Thermoplastics resins	0.0392
		Advertising services	0.0029	Crude steel (converters)	0.0099	Cyclic intermediates	0.0063	Air transport	0.0031	Nonferrous metal castings and forgings	0.0385
		Other rubber products	0.0024	Paper	0.0073	Aluminum (inc. regenerated aluminum)	0.0062	Ferro alloys	0.0031	Petrochemical basic products	0.0327
		Coated steel	0.0024	Air transport	0.0066	Other industrial organic chemicals	0.0050	Cement	0.0029	Aliphatic intermediates	0.0307
		Wholesale trade	0.0023	Motor vehicle parts and accessories	0.0061	Other resins	0.0044	Thermoplastics resins	0.0028	Plastic products	0.0305
		Harbor transport service	0.0023	Steel pipes and tubes	0.0056	Hired car and taxi transport	0.0038	Petrochemical aromatic products (except synthetic resin)	0.0024	Waste management services (private)	0.0300
		Sewage disposal	0.0020	Inorganic pigment	0.0053	Coated steel	0.0037	Synthetic rubber	0.0022	Coated steel	0.0282
		Hired car and taxi transport	0.0019	Waste management services (private)	0.0050	Industrial soda chemicals	0.0037	Research and development (intra-enterprise)	0.0019	Air transport	0.0226
		Coal products	0.0018	Electrical equipment for internal combustion engines	0.0050	Crude steel (electric furnaces)	0.0036	Other industrial organic chemicals	0.0018	Motor vehicle bodies	0.0219
30 sectors Subtotal	0.6983		1.1338		1.1338		1.0656		0.8655		4.8061
Subtotal	0.1076		0.7066		1.2059		1.1519		0.8970		5.2658
Cumulative	0.1076		0.8142		2.0201		3.1720		4.0689		1.1968
Cumulative/Grand total	0.0204		0.1546		0.3836		0.6024		0.7727		1.0000

Table 4. Generation of CO_2 by supply chains per production of a passenger car with a 2000 cc engine: Japan.

Auto: CO2		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	1.2545
		Iron and steel casting and forging	0.0405	Petroleum products	0.0456	Petroleum products	0.0296	Petroleum products	0.0152	Motor vehicles	0.1489
		Land transport including pipelines	0.0388	Nonferrous basic metals	0.0384	Nonferrous basic metals	0.0152	Cement	0.0063	Petroleum products	0.1239
		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	0.0872
		Synthetic fibers and resin	0.0146	Land transport including pipelines	0.0254	Cement	0.0113	Nonferrous basic metals	0.0051	Land transport including pipelines	0.0872
		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	0.0759
		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	0.0442
		Air transport	0.0119	Cement	0.0077	Coal and lignite	0.0050	Paper, paper products, and newsprint	0.0022	Cement	0.0313
		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	0.0186
		Trade	0.0055	Railway transport services	0.0055	Inorganic heavy chemicals	0.0031	Inorganic heavy chemicals	0.0016	Coal and lignite	0.0182
		Insurance	0.0046	Other nonmetallic mineral products	0.0052	Railway transport services	0.0031	Railway transport services	0.0014	Air transport	0.0180
		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	0.0169
		Hand tools and hardware	0.0041	Natural gas	0.0045	Other nonmetallic mineral products	0.0024	Natural gas	0.0012	Railway transport services	0.0150
		Railway transport services	0.0040	Trade	0.0037	Trade	0.0018	Other chemicals	0.0009	Inorganic heavy chemicals	0.0128
		Rubber products	0.0040	Air transport	0.0036	Other chemicals	0.0017	Trade	0.0008	Trade	0.0123
		Plastic products	0.0038	Coal products	0.0023	Air transport	0.0015	Fertilizers	0.0007	Natural gas	0.0092
		Other chemicals	0.0034	Other chemicals	0.0021	Coal products	0.0013	Crude oil	0.0006	Other chemicals	0.0087
		Banking	0.0033	Plastic products	0.0019	Crude oil	0.0010	Air transport	0.0006	Plastic products	0.0070
		Inorganic heavy chemicals	0.0020	Motor vehicles	0.0014	Fertilizers	0.0009	Coal products	0.0005	Insurance	0.0066
		Other transport equipment	0.0018	Banking	0.0013	Plastic products	0.0008	Plastic products	0.0003	Banking	0.0057
		Other nonelectrical machinery	0.0017	Insurance	0.0013	Construction	0.0006	Construction	0.0003	Rubber products	0.0053
		Miscellaneous metal products	0.0007	Construction	0.0010	Banking	0.0006	Banking	0.0002	Hand tools and hardware	0.0048
		Art silk and synthetic fiber textiles	0.0006	Iron ore	0.0009	Insurance	0.0004	Structural clay products	0.0002	Coal products	0.0045
		Communication	0.0006	Rubber products	0.0008	Structural clay products	0.0004	Insurance	0.0002	Fertilizers	0.0028
		Coal and lignite	0.0005	Communication	0.0007	Water transport	0.0004	Water transport	0.0002	Crude oil	0.0027
		Construction	0.0004	Hand tools and hardware	0.0006	Iron ore	0.0003	Other oil seeds	0.0002	Construction	0.0025
		Electronic equipments including TV	0.0004	Water transport	0.0006	Communication	0.0003	Communication	0.0001	Other nonelectrical machinery	0.0022
		Jute hemp and mesta textiles	0.0004	Miscellaneous manufacturing	0.0006	Storage and warehousing	0.0003	Storage and warehousing	0.0001	Other transport equipment	0.0021
		Community, social, and personal services	0.0003	Miscellaneous metal products	0.0005	Rubber products	0.0003	Jute hemp and mesta textiles	0.0001	Communication	0.0018
30 sectors subtotal	0.1347		1.9167		1.2333		0.6376		0.3020		4.4656
Subtotal	0.1347		1.9199		1.2387		0.6406		0.3035		4.4856
Cumulative	0.1347		2.0545		3.2933		3.9339		4.2374		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_2 by supply chains per production of a passenger car with a medium size engine: India.

Tables 4 and **5** show the amounts of CO_2 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_2 emissions

6.1. Relative contributions of direct and indirect CO_2 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_2 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.

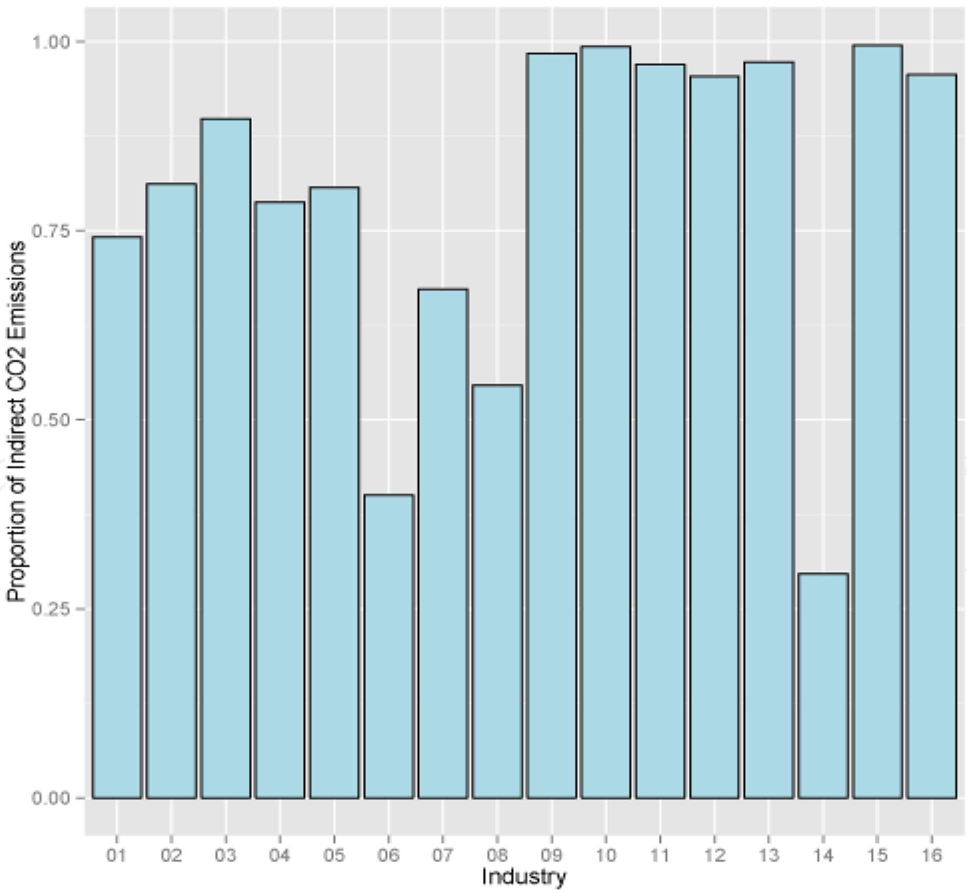

Figure 6. CO_2 emissions by industry: proportions of indirect emissions for India.

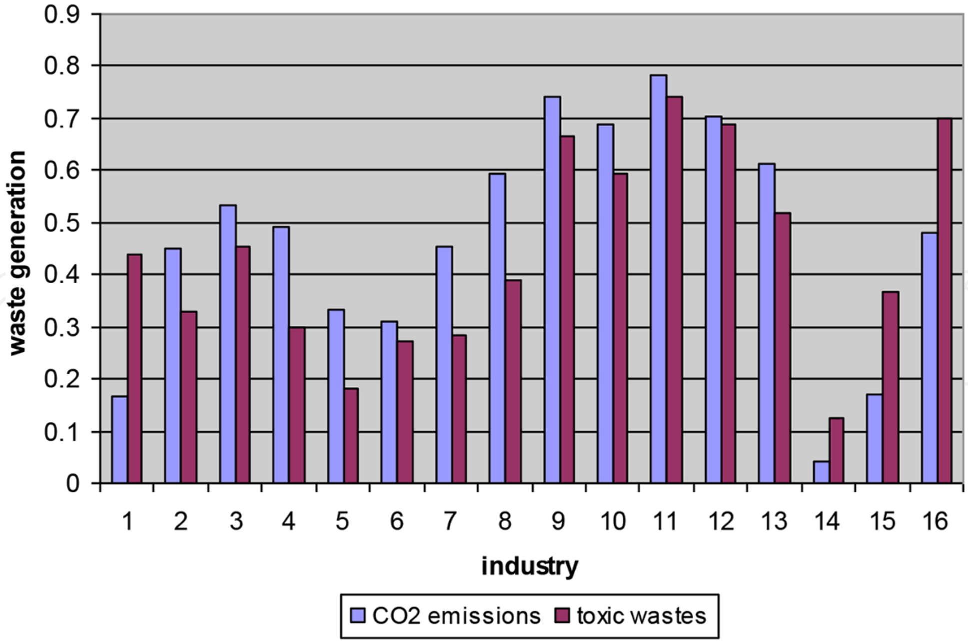

Figure 7. CO_2 emissions by industry: proportions of indirect emissions for Japan. Notes: In this graph for Japan, proportions of indirectly generated amounts of toxic waste (solid and liquid) materials other than CO_2 are also shown.

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**

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Are the patterns of CO_2 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_2 emissions as well as their own.

In general, we expect upstream firms' generation of toxic wastes such as CO_2 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***	0.6965***	0.4640***	0.5087***
	(0.0415)	(0.0578)	(0.0099)	(0.0204)
Direct CO_2waste (downstream)	−0.0043	0.0649**	−0.0018*	−0.0016
	(0.0034)	(0.0194)	(0.0011)	(0.0011)
Indirect CO_2waste (upstream total, all stages)	–	−0.1266***	–	−0.0150**
		(0.0347)		(0.0070)
Indirect CO_2waste (upstream, first stage)	−0.0107***	–	−0.0115***	–
	(0.0115)		(0.0030)	
Adjusted R^2	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 heteroskesdasticity 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_2 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_2 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_2 generated directly by downstream firms as well as the amounts of CO_2 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.[8]

Even though CO_2 is not thought to be one of the industrial wastes in a traditional sense, the amounts of CO_2 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_2, 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_2 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_2 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_2 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_2 occurs in their own production processes. Generation of CO_2 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_2 emissions along supply chains affect final sectors' value added. As far as final sectors' direct emissions are concerned, direct CO_2 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_2 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.[9] In all cases, indirect emissions from all supplier stages combined are statistically

[8] Various tests of heteroskedasticity and specification tests that we have done, respectively, show little heteroskedasticity and little specification errors.

[9] 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_2 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_2 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
Code	**Name**	**Code**	**Name**
81	Hand tools and hardware	116	Trade
82	Miscella neous 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	Miscell aneous 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_2equivalent): India, ton-CO_2per 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_2equivalent): Japan, ton-CO_2per 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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