Industrial Waste Generation and Management in Japan

A Supply Chain Based Analysis

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Abstract

Current public policies on waste management in Japan focus on firms and/or establishments as a unit of analysis. This may not be appropriate for an economy such as Japan's in which the decisions of many firms in many economic sectors are made at a supply chain level. This form of decision making has deepened in Japan's assembly-based manufacturing industries such as auto, electronic and machinery industries, where large downstream assembler firms tend to have some level of influence on their smaller upstream suppliers' business decisions. We present limited empirical evidence that suggests that downstream firms' performance is indeed affected by their upstream suppliers' waste output.

More specifically, using data that became available recently we estimate the amounts of toxic and non-toxic industrial wastes generated by Japanese manufacturers and their supply chains. We then estimate their contributions to firms' value added. We show, for example, that their upstream firms' generation of toxic waste has negative impacts on downstream firms' firm performance, suggesting the economic importance to downstream firms of their upstream firms' environmental practices. This might be a rationale underlying some downstream assembler firms' attempts to implement green procurement policies with their upstream suppliers.

KEYWORDS: Industrial waste management, supply chain, Japanese manufacturing industries

Introduction

Limiting the amounts of industrial wastes generated in firms' manufacturing processes has been of policy interest in recent years. One reason for this is that choosing appropriate methods of disposing of wastes is important given that only a limited number of landfill sites are available. Also the costs of collecting and recycling industrial wastes as well as treating them for reuse are rising (e.g., Kawamoto (2008), Memon (2010)). Another 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 coming to be regulated like toxic industrial wastes in many developed countries including Japan.

Governments have also introduced regulations to limit the amounts of toxic industrial wastes that firms generate. These environmental policies generally target firms and their establishments. One of the topics of research interest, which has not received much empirical attention, is the extent to which industrial wastes are generated along firms' supply chains. Although we see large corporations (e.g. 3M, Sony) promoting green procurement policies and claiming to use environmentally friendly suppliers, we have little empirical evidence yet to suggest how such supply chain based environmental management methods might benefit large downstream firms economically and also work in terms of actual reductions in the amounts of the waste generated in aggregate.

In this paper we use input-output (I-O) analysis (Leontief, 1970, 1986) to derive empirical estimates for the amounts of toxic and non-toxic industrial wastes generated by Japanese manufacturers and their supply chains. We then estimate their contributions to firms' value added. We show, for example, that their upstream firms' generation of toxic waste has negative impacts on downstream firms' firm performance, suggesting the economic importance to downstream firms of their upstream firms' environmental practices.[1]

Estimation of waste along a supply chain

In I-O analysis it is customary to include output which has economic value. 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 basic I-O analysis. Instead we treat waste materials separately here as shown below. Suppose x_j denotes the output from sector j. Then the 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} connects downstream output in sector j to its immediate predecessor upstream input from sector i.

We denote by A an nxn matrix with elements a_{ij} and by x an nx1 vector in which each component x_j represents domestic production (output) of sector j (j=1,2,..,n). We also denote by f_i the final downstream demand for sector i. We denote by f the corresponding nx1 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 $x^{(k=1)} = A f$.

$x^{(1)}$ 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

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in the immediate predecessor stage (denoted by k=2) in the supply chain is given by the i-th element of the following vector: $x^{(2)} = A x^{(1)} = A^2 f$.

Generally, we can trace production activities along the supply chain backward, starting from the final demand, and we get $x^{(k)} = A x^{(k-1)} = A^k f$, k=1,2,....
We call $x^{(k)}$ the k-th 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:
$x^{(indirect)} = A f + A^2 f + \ldots\ldots + A^k f + \ldots. = A (I - A)^{-1} f$,
where $(I - A)^{-1}$ is the Leontief inverse matrix which exists provided that the a_{ij} satisfy the Hawkins-Simon condition (Solow, 1952).

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.

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 nxn diagonal matrix with $E1_j$ in the j-th diagonal position. Then the amounts of waste produced by 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 w denotes an nx1 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
$w^{(0)} = E A^0 f = Ef$, 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
$w^{(1)} = E A x^{(0)} = E A f$.

Similarly we can derive the amount of waste generated along the upstream stages (k=2,3, ..,) of the supply chain as follows:
$w^{(k)} = E A x^{(k-1)} = A^k f$, k=2,3, ...
This is shown in the last row of Table 1.

In this paper we apply the above procedure for multiple waste materials associated with industrial production activities.

Data

Input-output matrix

In this paper we use the Japanese I-O table for Year 2000 with 399 sectors (n=399). In addition to the I-O matrix $A = \{a_{ij}$ (i,j = 1,2,...,n)$\}$ the Japanese I-O table includes additional information on relevant economic quantities for each of the 399 sector including final demand f for the Japanese economy.

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

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						
$x^{(indirect)} = A f + A^2 f + \ldots\ldots + A^k f + \ldots. = A(I-A)^{-1} f$	←←←	$x^{(n)} = A x^{(n-1)} = A^n f.$	←←←	$x^{(2)} = A x^{(1)} = A^2 f.$	$x^{(1)} = A f.$	f (direct output)
waste output generated along the stages of a supply chain						
$w^{(indirect)} = AEf + A^2 Ef + \ldots\ldots + A^k Ef + \ldots. = A(I-A)^{-1} Ef$	←←←	$w^{(n)} = A^n Ef$	←←←	$w^{(2)} = A^2 Ef$	$w^{(1)} = AEf$	Ef (direct waste generated)

Waste and By-Products Surveys and I-O matrix A

Japanese Ministry of Economy, Trade and Industry (METI) has been conducting annual Waste and By-Products Surveys of Japanese establishments sampled at the 4 digit industry level of the Japan standard industrial classification (JSIC). At this 4 digit level there are 562 SIC sectors q=562. In this paper we use responses from the 2006 Waste and By-Products Survey (WBPS). The sample consists of 5,048 establishments at 1,700 companies. Output from these establishments are classified into 562 SIC sectors. Denote output for the 562 SIC sectors by y, a qx1vector, In this survey these establishments also report the amounts of wastes and by-products they generated. Since these 562 SIC sectors are not identical to the 399 I-O sectors, it is necessary to rewrite the amounts of output as well as wastes reported for the SIC sectors in the survey for the I-O sectors. This is done by using a so-called bridge matrix, B, which relates output from each of the 562 SIC sectors to each of the 399 I-O sectors. B consists of elements b_{is} , i=1,2,..,n, s=1,2,..,q, n=399, q=562, where b_{is} represents the amount of input of I-O sector i that is required to produce the unit amount of output in SIC sector s. Matrix B is provided as part of the Japanese Input-Output tables.

Using B, output vector y for SIC sectors is rewritten as x=By, where output vector x in the I-O table denotes the total production of the Japanese economy and vector y denotes output for the sample being surveyed in the WBPS dataset. Matrix B bridges the two classification systems and also includes a scaling factor that blows up the sample output to that of the national economy.

Calculating the amounts of waste materials

The WBPS survey includes questions about the amounts of 37 types of wastes and by-products generated at establishments during their production processes. (These wastes and by-products are not individually discussed here to conserve space.)

Using the above procedure we used estimated quantities of wastes and by-products for each of 562 Japanese SIC sectors to derive the corresponding estimates for I-O sectors of the Japanese Input-Output table for Year 2000. In our regression analyses we also use value added estimated for each of these I-O sectors. More specifically, using I-O analysis we have estimated the amounts of wastes which are generated per unit output (one million yen worth of output) for each of the 399 I-O sectors.[2]

In this paper, for simplicity, we aggregate the above 37 wastes into two types, toxic and non-toxic wastes, and we focus our analysis primarily on these two categories. (We note, however, that it is possible to analyze these waste materials individually, or waste materials aggregated in different groups.)

In addition to the toxic and non-toxic wastes discussed above, we are also interested in studying the behavior of CO_2 in firms' decision processes. In this paper we denote by CO_2 emissions the total emissions in carbon dioxide equivalents of all greenhouse gases. The 37 waste materials listed above and CO_2 both have certain characteristics in common in terms of their implications for firms' own economic incentives and government regulations. For example, CO_2 emissions, like some of the above listed non-toxic waste, 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 CO2 emissions and fossil energy use are highly correlated (NIES (2010)).) We use our estimates for CO_2 emissions obtained elsewhere using estimated emissions data and the Japanese input-output database (Hayami and Nakamura (2007)).

Waste output along supply chains: auto industry example

One topic of research interest is to evaluate the relationships that might exist between downstream and upstream firms in terms of their waste behaviour. 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.

Auto industry example

[2] One million yen is worth about $9345.79 using the 2000 exchange rate of 107 yen per dollar.

Our calculations show the following downstream-upstream relationships in the generation of certain waste materials. The total amount of toxic “inorganic sludge polishing sand” generated directly and indirectly in Year 2000 from passenger car production is 53,962 tons. But most of this toxic material is produced in upstream industries, in particular the “Sheet glass and safety glass” industry produces 49,728 tons and “Electricity” generation required for car assembly produces 3,004 tons of this toxic material. The total amount of nontoxic “waste plastics other than synthetic rubber” from passenger car production is 61,800 tons, of which upstream “Motor vehicle parts and accessories” industries produce 31,729 tons and downstream “Passenger motor cars” assembly industry produces 28,188 tons.

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 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. Since our waste data are given for establishments (plants) classified into Japan SIC 4-digit industries, we use a bridge matrix (B) which transforms all output quantities give n the SIC code into I-O sector based quantities.

We have shown how we estimate production and waste output in each stage of a supply chain. We present our estimates below. Figures in Panels A, B and C of Table 2 correspond, respectively, to production of one passenger car with a 2000cc Japan standard engine by the final auto assembler.

We see from Panel A that 0.44355 tonnes (443.55 kg) of all toxic wastes combined is generated by supply chain’s current production activity to produce one passenger car. The final assembler firm generates about 3.7% of the total toxic wastes, while the rest, amounting to about 96% of the total toxic wastes generated by the entire supply chain, is actually generated by the suppliers and other firms involved in the upstream operations.

We see from Panel B that firms along the supply chain generates 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. This emission pattern along the supply chain is very similar to the pattern of toxic wastes generation reported in Panel A.

Panel C of Table 2 shows, on the other hand, that the final assembler firm generates 22% of 1.04909 tons of combined nontoxic wastes generated by the entire supply chain, while its upstream suppliers generate 78%. This is in contrast to the supply chain behaviour involving toxic wastes and also of CO_2. These results from Panels A, B and C are consistent with a number of alternative interpretations, one of which being that the dominant downstream firms tend to delegate the activities involving generation of toxic wastes and emissions of CO_2 to their upstream firms. The downstream firms may not mind keeping a relatively large fraction of its supply chain’s nontoxic waste generation activities.

Table 2. Supply chain effects, auto industry: wastes generated by production of one passenger car with a 2000cc engine

Waste generation stage: direct, indirect (1,2,3,4)	Amounts generated (tonnes)	Cumulative amounts (tonnes)[a]	Ratio to total
	Panel A: toxic wastes		
direct	0.016649	0.016649	0.037535
indirect (1st stage)	0.061244	0.077892	0.175611
indirect (2nd stage)	0.119776	0.197668	0.44565
indirect (3rd stage)	0.111914	0.309583	0.697965
indirect (4th stage)	0.070204	0.379787	0.856242
Total (all stages)	0.44355	0.443550	1
	Panel B: CO_2		
direct	0.107625	0.107625	0.020439
indirect (1st stage)	0.706568	0.814193	0.15462
indirect (2nd stage)	1.205888	2.020081	0.383625
indirect (3rd stage)	1.151894	3.171974	0.602376
indirect (4th stage)	0.896974	4.068948	0.772717
Total (all stages)	5.26577	5.265770	1
	Panel C: nontoxic wastes		
direct	0.227419	0.227419	0.216778
indirect (1st stage)	0.201553	0.428972	0.408899
indirect (2nd stage)	0.106076	0.535048	0.510012
indirect (3rd stage)	0.142937	0.677985	0.64626
indirect (4th stage)	0.161449	0.839433	0.800154
Total (all stages)	1.04909	1.04909	1

Source: Authors' calculation.
Notes: [a] Cumulative quantity excludes waste that has been processed/recycled out of the production process.

Based on results given in Table 2 we conclude that government environmental regulations about toxic wastes as well as greenhouse gas emissions need to include not only the final auto producers but also many upstream suppliers in order to be effective.

Even though downstream customer firms such as final auto assemblers could implement some level of green procurement on their parts suppliers, there may be limitations if, as in the U.S., the suppliers are independent firms and cannot be dictated by the assembler firms. On the other hand, most suppliers along auto supply chains in Japan are loosely related by weak equity relationships called supplier keiretsu relationships. For example, Toyota Motor is the final assembler for the Toyota supplier keiretsu in which so-called first-tier suppliers, second-tier suppliers, etc. are found. Toyota owns a small equity share (typically less than 25%) in their key first-tier suppliers while Toyota's ownership share varies depending on the relative importance to Toyota of each supplier. Similarly the first-tier suppliers own some of their key second-tier suppliers' equity, and so on. All Japanese auto assemblers as well as the core assembler firms of other assembler-based manufacturing industries generally form these supplier keiretsu groups with their suppliers and have strong influence on their suppliers' behavior. Under these conditions and given that the core assembler firms of these keiretsu groups are much bigger than their suppliers, we expect that, if implemented, green procurement policies at the final assembly firm would have some level of influence on their upstream suppliers.

For these reasons supply chain based environmental policies such as green procurement policies might be particularly important in Japan. This is not to say that downstream firms' green procurement policies and certain financial and/or business incentives may also have potentially important impacts on their independent upstream suppliers.

At this time, however, no such policies are in effect in Japan. Nor is there information about the effectiveness of such waste management policies in economic terms along supply chains. To fill the gap in the literature, we empirically show how value generated by various types of environmental behavior along the stages of a supply chain is distributed.

We noted that our results in Table 2 are consistent with the possibility that downstream firms might be able to upload to their upstream suppliers processing of toxic wastes and CO_2 in particular, while processing relatively large amounts of nontoxic wastes themselves in house. This could easily happen in practice, since processing toxic wastes is generally expensive but many nontoxic wastes have significant commercial value.

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. It is unclear, however, that the present form of toxic waste generation along supply chains, for example, maximizes their downstream firms' welfare.

Detailed processes of generation of toxic waste and CO_2 emissions by upstream and downstream firms are presented in Tables 3 and 4 (not shown here).

Estimating the contributions of direct and indirect wastes

We have noted above that generation of waste materials such as toxic wastes and CO_2 is skewed towards upstream firms in manufacturing supply chains. Is such a pattern consistent with downstream firms' profit maximization behaviour? In this section we investigate this using data on Japanese input-output sectors. We are interested in testing the following hypothesis:

H1: Downstream firms' performance (measured by their value added) is affected by their upstream firms' waste generation as well as their own.

We expect upstream firms' generation of toxic wastes and CO_2 will 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.

We test this hypothesis empirically by estimating the following regressions using a sample of economic sectors corresponding to Japanese input-output sectors for which usable data are available. The data used includes value added and the amounts of wastes generated during direct and indirect stages of production for each of the input-output sectors in the sample. In our specification we regress value added on the amounts of wastes generated directly by downstream firms as well as the amounts of wastes generated indirectly by their upstream producers. Our OLS regression results are given in Tables 5 and 6 (not shown here). In these Tables we present heteroskedasticity-corrected standard errors, since various tests of heteroskedasticity show little to modest levels of heteroskedasticity are present in our regressions. We see from regressions reported in (C) and (D) in Table 6 that upstream firms' indirect toxic waste output as well as CO_2 emissions from all stages combined has negative impacts on value added. As before indirect nontoxic waste output contributes positively to downstream firms' value added.

We conclude that our hypothesis H1 is accepted.

Our results show that downstream firms' performance measured by their value added is affected by environmental performance of the upstream firms in their supply chains in a systematic way. In addition to the immediate negative impacts of waste output in their own production processes, downstream firms' performance is affected by what their upstream counterparts do environmentally. We speculate that there are multiple channels through which upstream firms' environmental policies affect downstream firms' value added. For example, upstream firms' use of fossil fuels reflected in CO_2 emissions and cleaning up of toxic wastes add to the cost of their production output, which in turn is passed to their downstream firm customers.

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