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An Empirical Examination of the Pollution Haven Hypothesis for India: Towards a Green Leontief Paradox?

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Abstract. Using input–output analysis, we examine whether India can be regarded as a pollution haven. We calculate the extra CO_2, SO_2 and NO_x emissions induced by 1 billion rupees of additional exports. This is compared with the reduction of Indian pollution caused by an import increase of equal size. In contrast to what the pollution haven hypothesis states for developing countries, we find that India considerably gains from extra trade. Comparing 1996/1997 with 1991/1992, the gains have only increased, indicating that India has moved further away from being a pollution haven. The outcome is robust to changes in the underlying assumptions.

Key words: international trade, environment, pollution haven, input–output analysis

JEL classifications: F18, Q32, D57

1. Introduction

International trade allows a country to partially disconnect its domestic economic and ecological systems, because some of the consumed goods are produced in other countries (Daly 1993; Pearce and Warford 1993; Proops et al. 1999). The environmental impacts of producing such goods affect the ecological system of the exporting country (where production takes place) rather than the ecological system of the importing country (where consumption occurs). In this sense trade allows countries to move away from producing environmentally sensitive (in terms of natural resources and pollution) activities.

The dominant trend in the world economy in the 1990s was towards liberalization of trade. The debate on the impacts of trade for the environment has gained much importance because of the Kyoto and Montreal Protocols and the discussions on the role of greenhouse gas emissions for global warming and climate change (see, for example, UNFCCC 1992; Wyckoff and Roop 1994). One of the environmental impacts typically discussed in connection with trade liberalization are the composition effects.[1] These occur when increased trade leads countries to specialize in industries where they enjoy a comparative advantage.

If this advantage stems from differences in production technologies, it may well be that both partners benefit – in terms of pollution – from trade. Although industries in developing countries are generally characterized by pollution intensities (i.e. per unit of gross output) that are higher than in developed countries, mutual benefits are certainly possible. In a Ricardian world with two countries and two goods, each country would export (and specialize in) the good in which it has a comparative advantage. That is, the good for which the pollution intensity (relative to the other country's intensity) is the least. In this framework, pollution is the only factor that accounts and it determines the price differences between the countries. Although this model is unlikely to apply to real world trade, it does indicate that mutual benefits can be obtained when pollution intensities are sufficiently taken into account.

If the comparative advantage stems from differences in environmental stringency, we arrive at a case that can be interpreted within the Heckscher–Ohlin (HO) theory. In its simplest form – with two countries, two goods, and two factors (labor and capital) – the HO model predicts that the relatively labor abundant country will export the good that is produced relatively labor intensive and will import the relatively capital intensive good. As an extension, it has been argued to include natural resources as a third factor (see, for example, Leamer 1980, 1984; Bowen et al. 1987). When pollution is restricted, it may be argued that "emission permits" play a role as a third factor. Developing countries are commonly believed to be relatively well endowed with emission permits, for various reasons. We would thus expect developing countries to be relatively abundant in emission permits and, according to the HO theory, to have a comparative advantage in (and therefore export) relatively emission intensive goods. As a consequence, trade will exacerbate existing environmental problems in the developing countries with relatively lax regulations. In other words, because the pollution regulations are stronger or the restrictions on emissions are tighter in developed countries than in developing countries, the latter will export "dirty" products and import "clean" products. This is the (trade-based version of the) pollution haven hypothesis, which may thus be viewed as a result of the HO model.

An important factor in determining the direction of trade is the endowment of pollution permits, which is larger for developing countries than for developed countries. Several causes contribute to this. First, the higher incomes in the developed countries generate a greater demand for clean air and water. Similarly, in developing countries, with lower levels of income and higher discount rates, extra earnings and jobs are valued higher, relative to health and less pollution. Second, the relative costs of monitoring and enforcing pollution standards are higher in developing countries, given the scarcity of trained personnel, the difficulty of acquiring sophisticated equipment and the high marginal costs of undertaking such a new governmental activity (when the policy focus is usually on reducing fiscal burdens). Third, growth in developing countries results in a shift from agriculture to manufacturing with rapid urban growth and substantive investments in urban infrastructure, all of which raise the pollution intensity. In developed countries, however, growth is associated with a shift from manufacturing to services, leading to a decrease of the pollution intensity. Fourth, the size of the informal sector in the economy is larger for developing countries.

It is thus hypothesized that free trade will induce displacement of "dirty" industries from developed countries with stricter environmental regulations, and will raise the competitive pressure on developing countries to reduce further their environmental standards. Although the trade-based version of the pollution haven hypothesis has received ample attention in the literature, empirical tests still seem to be largely lacking.[2] In this paper we analyze the pollution haven effect for India and its development over time. India is a developing country for which the assumption of lax regulations (and its underlying causes) does apply, in particular when compared with its major trading partners.[3] The regime in India is essentially of a command and control nature, consisting largely of environmental standards for different industrial activities. The lack of enforcement of environmental regulations has resulted in environmental degradation. The existing regulations have failed to induce polluters to undertake measures to cut back on pollution or find ways to improve their resource efficiency. For example, in a study on air quality, Sawhney (2004) reports that in 1997 only 19 out of the 70 cities under consideration had pollutant levels below the permissible limit.

Using an input–output framework, we calculate the pollution content of 1 billion rupees of Indian exports and compare it with the pollution content that would have been involved in producing 1 billion rupees of Indian imports at home (i.e. in India). So, leaving the current account balance of India as it is, we answer the question whether extra trade is beneficial in terms of pollution. For a pollution haven, we would expect a negative answer.

The plan of the paper is as follows. In Section 2, we present the underlying model and the input–output techniques. The pollution haven hypothesis in the context of the model is discussed in Section 3. The empirical tests for India are carried out in Section 4, for the emissions of carbon, sulphur and nitrogen dioxides. Our central finding is that India gains – in terms of pollution – from extra trade. The production of its exports is "cleaner" than the domestic production of its imports would have been, which rejects the HO theory. Section 5 presents our conclusions and argues that both the rejection and the underlying calculations resemble the famous study that has led to the Leontief (1953) paradox. This raises the question whether our findings point at a green Leontief paradox?

2. Methodology

Our starting point is the open, static input–output model (see e.g. Miller and Blair 1985, for an introduction), which is expressed as[4]

$$\mathbf{z} = \mathbf{A}\mathbf{z} + \mathbf{y} \tag{1}$$

where $\mathbf{z}$ is the $k \times 1$ vector of gross output in each of the k commodities, $\mathbf{A}$ is the $k \times k$ matrix of input coefficients, and $\mathbf{y}$ is the $k \times 1$ vector of final demands (including private and government consumption and investments, gross exports and inventory changes). Because the data used to implement the model are taken from input–output tables in money terms, gross outputs and final demands are in million rupees (mrs). The input coefficients a_{ij} are obtained as $a_{ij} = d_{ij}/z_j$, where d_{ij} denotes the domestic intermediate deliveries in mrs of commodity i to industry j. So, the input coefficient a_{ij} thus indicates the input in mrs of commodity i per mrs of output of commodity j.

Equation (1) can be rewritten as $(\mathbf{I} - \mathbf{A})\mathbf{z} = \mathbf{y}$, where $\mathbf{I}$ indicates the identity matrix. Expressing the gross outputs in terms of final demands yields $\mathbf{z} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{y}$ as the solution of the input–output model. Assuming fixed input coefficients, for any exogenously specified final demand vector $\tilde{\mathbf{y}}$, the gross outputs are given by $\tilde{\mathbf{z}} = (\mathbf{I} - \mathbf{A})^{-1}\tilde{\mathbf{y}} = \mathbf{L}\tilde{\mathbf{y}}$, where $\mathbf{L} = (\mathbf{I} - \mathbf{A})^{-1}$ denotes the Leontief inverse. Because the model is linear we can also write $(\Delta\mathbf{z}) = (\mathbf{I} - \mathbf{A})^{-1}\Delta\mathbf{y} = \mathbf{L}(\Delta\mathbf{y})$ which gives the extra gross outputs corresponding to an arbitrary (but exogenously specified) vector $\Delta\mathbf{y}$ of additional final demands.

An alternative viewpoint is obtained by considering the requirements that are necessary to satisfy an additional final demand of $\Delta\mathbf{y}$. First of all, $\Delta\mathbf{y}$ must be produced itself and for this, inputs to the amount of $\mathbf{A}(\Delta\mathbf{y})$ are required. These extra inputs, however, need to be produced themselves and require $\mathbf{A}^2(\Delta\mathbf{y})$ of inputs. In its turn, producing these inputs requires $\mathbf{A}^3(\Delta\mathbf{y})$ of inputs, and so forth. Summing over all the terms, yields the extra production that is – directly and indirectly – required to satisfy the extra final demands $\Delta\mathbf{y}$. That is, $(\Delta\mathbf{y}) + \mathbf{A}(\Delta\mathbf{y}) + \mathbf{A}^2(\Delta\mathbf{y}) + \mathbf{A}^3(\Delta\mathbf{y}) + \cdots = (\mathbf{I} + \mathbf{A} + \mathbf{A}^2 + \mathbf{A}^3 + \cdots)(\Delta\mathbf{y})$. Under the usual assumptions, the power series of matrices equals the Leontief inverse, i.e. $\mathbf{I} + \mathbf{A} + \mathbf{A}^2 + \mathbf{A}^3 + \cdots = (\mathbf{I} - \mathbf{A})^{-1} = \mathbf{L}$.

For the interpretation of the typical element l_{ij} of the Leontief inverse, take the jth unit vector for $\Delta\mathbf{y}$. That is, $\Delta y_j = 1$ and $\Delta y_k = 0$ for all $k \neq j$. Then $(\Delta\mathbf{z}) = \mathbf{L}(\Delta\mathbf{y})$ yields the jth column of the Leontief inverse $\mathbf{L}$. That is,

$\Delta z_i = l_{ij}$, which denotes the (extra) output of commodity i (in mrs), required per mrs of (extra) final demand for commodity j.

The next step is to calculate how much extra input of fossil fuels is required to produce $\Delta\mathbf{z}$, and therefore is required (directly and indirectly) to satisfy extra final demands $\Delta\mathbf{y}$. The fossil fuels are given by commodities 1 (coal and lignite) and 2 (crude petroleum and natural gas) – which shall be termed coal and oil for short. It is assumed that all the coal and oil are combusted whenever they are used as an intermediate input, generating CO_2, SO_2 and NO_x emissions. It should be noted that it is not necessary that if, for example, the industry that produces fertilizers uses inputs of crude oil, the actual combustion of crude oil takes place in that industry. The assumption is that somewhere in the entire production process that leads to a certain final demand (e.g. for fertilizers), all directly and indirectly required coal and oil is combusted.

Let us indicate the first two rows (corresponding to coal and oil) of the input coefficients matrix $\mathbf{A}$ by $\mathbf{a}_1'$ and $\mathbf{a}_2'$, respectively.[5] The jth element of the row vector $\mathbf{a}_1'$ then expresses the amount (in mrs) of *domestically produced* coal used as input for 1 mrs of output of commodity j. To find the input of coal that is actually combusted, we have to add the imported coal per mrs of output in industry j. Let this be denoted by the elements of the vector $\mathbf{b}_1'$ for coal and $\mathbf{b}_2'$ for oil. So, the vector $\mathbf{a}_1' + \mathbf{b}_1'$ gives the total amount of coal (in mrs) used as an input per mrs of output. An arbitrary change $\Delta\mathbf{y}$ in the final demands, requires the outputs to change by $\Delta\mathbf{z} = \mathbf{L}(\Delta\mathbf{y})$, implying a change in the input of coal to the amount of $(\mathbf{a}_1' + \mathbf{b}_1')(\Delta\mathbf{z}) = (\mathbf{a}_1' + \mathbf{b}_1')\mathbf{L}(\Delta\mathbf{y})$. To obtain the interpretation of the elements of the vector $(\mathbf{a}_1' + \mathbf{b}_1')\mathbf{L}$, take $\Delta\mathbf{y}$ equal to the jth unit vector again. It then follows that the jth element of the vector $(\mathbf{a}_1' + \mathbf{b}_1')\mathbf{L}$ gives the extra input of coal in mrs (both domestically produced and imported) per extra mrs of final demand for product j. The extra inputs in mrs of oil are given by $(\mathbf{a}_2' + \mathbf{b}_2')\mathbf{L}$.

The inputs of the fossil fuels coal and oil (which are assumed to be combusted) in mrs have to be “converted” into the generation of emissions. The conversion factors have been estimated following the guidelines of the Intergovernmental Panel on Climate Change (IPCC). The amounts of coal and oil in mrs are “translated” first to million tons of oil equivalent (mtoe), which are then converted into million tons (mt) of emissions.

For the empirical application in Section 4 we have used the input–output table for 1991/1992 in current prices and the 1996/1997 table in constant 1991/1992 prices.[6] In principle, the translation of mrs of coal into mtoe of coal should be the same over time, because the effects of price changes have been singled out. In the actual case, however, this does not hold exactly. It should be borne in mind, that the commodities in an input–output table are aggregates themselves, consisting of many sub-commodities for which no data are made available. The mix of sub-commodities within a single commodity may thus change over time. As a consequence, the mtoe/mrs ratio for a single commodity may differ across time, even if this ratio is constant for each sub-commodity. Recall that the first commodity covers coal and lignite and the second commodity includes crude petroleum and natural gas, so that changes in the mix do affect the translation. For coal (and lignite), for example, we find an mtoe/mrs ratio of 0.0026 in 1991/1992.

Next the mtoe of coal and lignite, for example, have to be converted into mt of CO_2 emission. The IPCC guidelines basically follow the equation for the greenhouse gas measure, which is applicable for CO_2, SO_2 and NO_x. The emission is obtained from the multiplication of four determinants. These are: (1) the total energy consumption; (2) the emission factor; (3) the molecular weight ratio; and (4) the fraction of e.g. carbon that is oxidized. The carbon emission factor of coal, for example, depends on the type of coal, where moisture, volatile matter, fixed carbon, ash, and sulphur play a role. For the present study we have used an average emission factor of 0.55 mt of carbon per mtoe of coal (see Mukhopadhyay 2002). The fraction of carbon that is oxidized amounts to 98% (which is also the fraction for sulphur and nitrogen). The molecular weight of CO_2 is 44 and that of C is 12, so that the molecular weight ratio equals $44/12 = 3.66$ mt of CO_2 per mt of C. Hence, the combustion of 1 mtoe of coal implies that $0.55 \times 0.98 \times (44/12) = 1.976$ mt of CO_2 are generated. Combining the two steps yields that the combustion of 1 mrs of coal generates $0.0026 \times 1.976 = 5.1376 \times 10^{-3}$ mt of CO_2. We denote this conversion factor by c_1, where the subscript 1 indicates the combustion of coal. Subscript 2 is used for the combustion of oil, and s and n are used for the generation of SO_2 and NO_x emissions (in mt), respectively. The conversion factors are given in Table I.

The jth element of the vector $c_1(\mathbf{a}_1' + \mathbf{b}_1')\mathbf{L}$ now indicates the (extra) emission of CO_2 (in mt) that is required for the production of one (extra) mrs of final demand of commodity j, due to the combustion of coal. The (extra) emission of CO_2, due to the combustion of coal and oil, per (extra) unit of final demand would be given by the elements of the vector $[c_1(\mathbf{a}_1' + \mathbf{b}_1') + c_2(\mathbf{a}_2' + \mathbf{b}_2')]\mathbf{L}$. For any exogenously specified final demand change $\Delta\mathbf{y}$, the extra total emission of CO_2 (given as a scalar) would amount to $[c_1(\mathbf{a}_1' + \mathbf{b}_1') + c_2(\mathbf{a}_2' + \mathbf{b}_2')]\mathbf{L}(\Delta\mathbf{y})$. More detail with respect to the ultimate causes of the pollution is obtained from the vector $[c_1(\mathbf{a}_1' + \mathbf{b}_1') + c_2(\mathbf{a}_2' + \mathbf{b}_2')]\mathbf{L}(\Delta\hat{\mathbf{y}})$.[7] The jth element of this vector gives the extra CO_2 emissions that are directly and indirectly required to satisfy the extra final demand Δy_j. Similar expressions hold for the emissions of SO_2 and NO_x, using the appropriate conversion factors.

Table I. Conversion factors

	Emissions in million tons		
1991/1992	CO_2	SO_2	NO_x
Combustion of 1 million rupees (mrs) of:		$\times 10^{-3}$	
Coal & lignite	$c_1 = 5.1376$	$s_1 = 0.0156$	$n_1 = 0.1534$
Crude petroleum & natural gas	$c_2 = 3.1548$	$s_2 = 0.0330$	$n_2 = 0.0033$
1996/1997			
Combustion of 1 mrs of:		$\times 10^{-3}$	
Coal & lignite	$c_1 = 4.9143$	$s_1 = 0.0149$	$n_1 = 0.1467$
Crude petroleum & natural gas	$c_2 = 2.2944$	$s_2 = 0.0240$	$n_2 = 0.0024$

3. Testing the Pollution Haven Hypothesis

Let us assume that the world consists of two countries or regions, North and South. In the empirical application in Section 4, we use India for South and the rest of the world (RoW) as North. In our examination of the pollution haven hypothesis, we will compare the current situation with the situation where trade has increased and calculate the effects in terms of extra CO_2, SO_2 and NO_x emissions. It is assumed that both the imports and the exports are increased by the same amount of money, so that the balance of the current account remains unaffected. The vectors of changes in the exports and imports are denoted by $\Delta\mathbf{e}$ and $\Delta\mathbf{m}$, respectively, and the indexes for North and South are *N* and *S*, respectively. So, $\Delta\mathbf{e}_N = \Delta\mathbf{m}_S$ indicates the changes in the exports of North and the imports of South, which are equal to each other in a two-country setting. Similarly, we have $\Delta\mathbf{e}_S = \Delta\mathbf{m}_N$. Note that the total value of the changes in imports and exports is the same, so that the elements in the vectors have the same sum. That is $\Sigma_i(\Delta e_S)_i = \Sigma_i(\Delta m_S)_i$.

In Section 2, we have seen that the *j*th element of the vector $[c_1(\mathbf{a}'_1 + \mathbf{b}'_1) + c_2(\mathbf{a}'_2 + \mathbf{b}'_2)]\mathbf{L}$ indicates the (extra) emission of CO_2 (in mt) that is required for the production of one (extra) mrs of final demand of commodity *j*, due to the combustion of coal and oil. Let us write this as $\gamma'_N\mathbf{L}_N$ for North and as $\gamma'_S\mathbf{L}_S$ for South. The increase in the exports of South implies that the emissions are raised by $\gamma'_S\mathbf{L}_S(\Delta\mathbf{e}_S)$. The increase in imports by South implies that these goods are now no longer produced at home, which yields less emissions to the amount of $\gamma'_S\mathbf{L}_S(\Delta\mathbf{m}_S)$. If we write $\Delta\pi_S$ for the extra emissions in South as caused by increased trade, we have $\Delta\pi_S = \gamma'_S\mathbf{L}_S(\Delta\mathbf{e}_S - \Delta\mathbf{m}_S)$. If South is a developing country, the pollution haven hypothesis states that South is left worse off (in terms of pollution) by an increase in trade. That is, for South the total amount of emissions is larger than it was before, $\Delta\pi_S > 0$. However, $\Delta\pi_S$ being positive, is only one side of the story. Let $\Delta\pi_N = \boldsymbol{\gamma}'_N\mathbf{L}_N(\Delta\mathbf{e}_N - \Delta\mathbf{m}_N)$ denote the extra emissions in North due to increased trade. In order for South to be a pollution haven, North must benefit (in environmental terms) from trade. That is, $\Delta\pi_N < 0$. Because the exports of the one are the imports of the other, we may also write $\Delta\pi_N = -\boldsymbol{\gamma}'_N\mathbf{L}_N(\Delta\mathbf{e}_S - \Delta\mathbf{m}_S) < 0$.

At the world level, an increase of trade is beneficial if the total amount of extra emissions decreases. That is, if $\Delta\pi_S + \Delta\pi_N = (\boldsymbol{\gamma}'_S\mathbf{L}_S - \boldsymbol{\gamma}'_N\mathbf{L}_N)\times(\Delta\mathbf{e}_S - \Delta\mathbf{m}_S) < 0$. Note that the extra flow of goods from North to South (i.e. $\Delta\mathbf{e}_N = \Delta\mathbf{m}_S$) increases the pollution in North by $\boldsymbol{\gamma}'_N\mathbf{L}_N(\Delta\mathbf{e}_N) = \boldsymbol{\gamma}'_N\mathbf{L}_N(\Delta\mathbf{m}_S)$ and changes (i.e. reduces) pollution in South by $-\boldsymbol{\gamma}'_S\mathbf{L}_S(\Delta\mathbf{m}_S)$. The change at world level thus amounts to $-(\boldsymbol{\gamma}'_S\mathbf{L}_S - \boldsymbol{\gamma}'_N\mathbf{L}_N)(\Delta\mathbf{m}_S)$. The extra flow from South to North, increases pollution in South by $\boldsymbol{\gamma}'_S\mathbf{L}_S(\Delta\mathbf{e}_S)$, changes pollution in North by $-\boldsymbol{\gamma}'_N\mathbf{L}_N(\Delta\mathbf{m}_N) = -\boldsymbol{\gamma}'_N\mathbf{L}_N(\Delta\mathbf{e}_S)$, and yields a change at world level of $(\boldsymbol{\gamma}'_S\mathbf{L}_S - \boldsymbol{\gamma}'_N\mathbf{L}_N)(\Delta\mathbf{e}_S)$.

Note that if technology is the same in both countries, we have $\boldsymbol{\gamma}'_S = \boldsymbol{\gamma}'_N$ and $\mathbf{L}_S = \mathbf{L}_N$. As a consequence, the extra emissions at the world level $(\Delta\pi_S + \Delta\pi_N)$ are zero. This is not surprising because at the world level it doesn't matter whether the products are produced in North or in South, when the technologies are the same. This also implies that the gains (in terms of extra pollution) of the one are the losses of the other, i.e. $\Delta\pi_S = -\Delta\pi_N$.

In general, technologies will be different and we have four possible outcomes. First, $\Delta\pi_S < 0$ and $\Delta\pi_N < 0$. In this case, both countries benefit from increased trade. It occurs if both countries export the products in which they have a comparative advantage from the viewpoint of their technology (i.e. trade is in line with the Ricardian theory). Second, $\Delta\pi_S > 0$ and $\Delta\pi_N > 0$. Both countries clearly lose from trade. North (South) exports products for which the production is polluting at home but relatively clean in South (North). This case of anti-Ricardian behaviour is unlikely to occur and both countries would gain by a complete trade reversal (i.e. if, instead of importing a product, exactly the same amount were exported, and vice versa). Third, $\Delta\pi_S < 0$ and $\Delta\pi_N > 0$, in which case South gains from extra trade, whereas North loses. The fourth case reflects the pollution haven hypothesis, where North gains at the cost of South. That is, $\Delta\pi_S > 0$ and $\Delta\pi_N < 0$. At the world level, the first case is clearly beneficial while the second is not. For the third and fourth case, it depends on the sum $(\Delta\pi_S + \Delta\pi_N)$, whether there are gains (<0) or losses (>0) at the world level.

4. An Empirical Application to India

For our empirical application, we have used the 60×60 commodity by commodity input–output tables for India in the years 1991/1992 and 1996/1997 (see Planning Commission 1995, 2000). The CO_2, SO_2 and NO_x emissions from fossil fuel combustion have been estimated on the basis of the guidelines provided by the IPCC. To make the commodity classification comparable between the two data sets, the input–output tables had to be aggregated to 43 × 43 tables. In order to obtain comparability over time, the 1996/1997 table was expressed in 1991/1992 prices using the appropriate price indexes. (See Table A1 in the Appendix for the commodity classification.)

The results are given in Table II. Using *I* for India, instead of *S* for South, columns (2) and (3) indicate $\Delta\mathbf{e}_I$ and $\Delta\mathbf{m}_I$, respectively. We have calculated the extra pollution due to an increase in trade of 1 billion rupees, leaving the balance on the current account invariant. So, for example, if the actual export vector in 1991/1992 is denoted by $\mathbf{e}_I^{1991/1992}$ then $\Delta\mathbf{e}_I = (1000/557,166)\mathbf{e}_I^{1991/1992}$, where the 557,166 is the total amount of exports (in mrs) in 1991/1992. The vector $\Delta\mathbf{e}_I$ in column (2) gives the extra exports (in mrs) of each commodity if total exports increase by 1 billion rupees. Note that the vector reflects the shares of each commodity in the actual exports of 1991/1992 (i.e. division by 10 gives the percentage contribution to total exports of each commodity). For example, 12.9% of the Indian exports in 1991/1992 concerned Other Textiles (commodity 19).

The multipliers in column (4) are given by the elements of the vector $\boldsymbol{\gamma}_I'\mathbf{L}_I$ and indicate the (extra) emission of CO_2 (in 1000 tons) that is required per (extra) mrs of final demand of commodity *j*. Multiplying, for commodity *j*, the multiplier with the extra exports gives the extra pollution in column (5), which corresponds to the row vector $\boldsymbol{\gamma}_I'\mathbf{L}_I(\Delta\hat{\mathbf{e}}_I)$.

The most important conclusion from Table II (and Table A2 in the Appendix, for 1996/1997) is that India cannot be characterized as a pollution haven. The idea was that an increase of trade implies extra pollution because exports increase, but less pollution because imports increase (which are no longer produced at home anymore). For a pollution haven, the first effect is larger than the second effect, so that there will be a net increase in pollution. Pollution havens export "dirty" products and import goods whose domestic production is relatively "clean". It is clear from the totals in Table II that the import related pollution is much larger than the export related pollution in India, so that India gains (in terms of emissions) from trade. Note that for a country to be characterized as a pollution haven, it was necessary that the country itself loses from trade, while its trading partner (RoW in the present case) gains. The pollution haven hypothesis can thus be accepted only if both requirements are fulfilled (i.e. $\Delta\pi_S = \Delta\pi_I > 0$ and $\Delta\pi_N = \Delta\pi_{\mathrm{RoW}} < 0$). Because input–output data for the RoW are lacking, it is not possible to fully test the pollution haven hypothesis. For its rejection, however, it suffices if one of the two requirements fails to be met, as is the case for India, with total export pollution being substantially smaller than total import pollution.

Comparing the results for the 2 years strengthens this conclusion. Not only are the Indian exports cleaner than the goods that are replaced by

Table II. Emissions from 1 billion rupees of extra exports and imports, 1991/1992

Commodity (1)	Trade		CO_2			SO_2			NO_x		
	Export (2)	Import (3)	Multiplier (4)	Export pollution (5) = (4) × (2)	Import pollution (6) = (4) × (3)	Multiplier (7)	Export pollution (8) = (7) × (2)	Import pollution (9) = (7) × (3)	Multiplier (10)	Export pollution (11) = (10) × (2)	Import pollution (12) = (10) × (3)
1	0.36	5.38	0.12	0.04	0.65	0.72	0.26	3.90	2.25	0.80	12.08
2	0.00	79.62	0.07	0.00	5.25	0.56	0.00	44.45	0.58	0.00	46.19
3	0.16	0.00	0.59	0.10	0.00	2.17	0.35	0.00	16.15	2.61	0.00
4	8.74	7.26	0.10	0.91	0.75	0.82	7.18	5.96	1.14	9.92	8.24
5	0.00	0.00	0.06	0.00	0.00	0.50	0.00	0.00	0.68	0.00	0.00
6	0.00	0.15	0.01	0.00	0.00	0.11	0.00	0.02	0.17	0.00	0.03
7	14.70	2.28	0.11	1.66	0.26	0.92	13.54	2.11	1.14	16.75	2.60
8	8.19	0.00	0.02	0.17	0.00	0.15	1.23	0.00	0.28	2.28	0.00
9	0.00	0.12	0.05	0.00	0.01	0.37	0.00	0.05	0.53	0.00	0.07
10	44.23	3.87	0.04	1.98	0.17	0.37	16.57	1.45	0.41	18.32	1.60
11	3.13	6.30	0.03	0.10	0.20	0.25	0.77	1.55	0.36	1.11	2.24
12	0.00	8.53	0.03	0.00	0.22	0.24	0.00	2.01	0.18	0.00	1.55
13	21.91	0.05	0.05	1.19	0.00	0.51	11.20	0.03	0.28	6.22	0.02
14	13.41	96.78	0.11	1.50	10.84	0.88	11.75	84.79	1.26	16.93	122.18
15	0.75	0.14	0.10	0.07	0.01	0.74	0.56	0.11	1.20	0.90	0.17
16	0.00	0.22	0.15	0.00	0.03	0.87	0.00	0.19	2.84	0.00	0.63
17	28.78	8.92	0.10	2.78	0.86	0.65	18.64	5.78	1.50	43.27	13.42
18	48.03	0.96	0.15	7.15	0.14	0.91	43.69	0.87	2.67	128.30	2.57
19	128.74	9.20	0.10	12.94	0.92	0.59	76.53	5.47	1.88	241.71	17.27
20	0.40	0.73	0.04	0.01	0.03	0.26	0.11	0.19	0.49	0.20	0.36
21	0.71	15.41	0.20	0.14	3.13	1.00	0.71	15.41	4.59	3.26	70.71

22	60.49	0.93	0.06	3.62	0.06	0.41	24.76	0.38	0.90	54.58	0.84
23	19.43	1.31	0.08	1.53	0.10	0.56	10.92	0.73	1.09	21.19	1.43
24	4.19	1.45	0.06	0.23	0.08	0.38	1.60	0.55	0.82	3.42	1.18
25	19.66	67.83	1.73	34.09	117.65	17.08	335.70	1158.39	5.95	116.90	403.40
26	0.05	25.52	0.48	0.02	12.18	3.77	0.20	96.17	5.25	0.27	133.90
27	2.15	1.92	0.08	0.17	0.15	0.56	1.20	1.07	1.11	2.38	2.13
28	51.02	107.21	0.14	6.98	14.66	0.98	49.78	104.62	1.91	97.29	204.44
29	0.00	0.05	0.36	0.00	0.02	1.47	0.00	0.08	9.42	0.00	0.52
30	7.05	3.41	0.28	1.98	0.96	1.64	11.56	5.58	5.32	37.53	18.12
31	6.01	33.63	0.35	2.11	11.78	1.96	11.77	65.82	6.99	42.05	235.22
32	2.60	17.82	0.28	0.72	4.94	1.94	5.03	34.49	4.03	10.49	71.87
33	31.09	178.73	0.13	3.90	22.43	0.78	24.20	139.10	2.21	68.55	394.10
34	12.86	28.75	0.10	1.30	2.91	0.66	8.53	19.07	1.64	21.13	47.26
35	0.45	8.94	0.05	0.02	0.49	0.36	0.16	3.23	0.88	0.39	7.91
36	8.55	35.53	0.06	0.54	2.25	0.42	3.57	14.84	1.01	8.68	36.06
37	17.86	47.99	0.09	1.56	4.19	0.57	10.20	27.42	1.42	25.36	68.15
38	100.00	48.87	0.12	11.52	5.63	0.68	68.35	33.40	2.14	214.35	104.75
39	0.00	0.00	0.12	0.00	0.00	0.75	0.00	0.00	2.19	0.00	0.00
40	68.72	85.95	0.22	15.36	19.21	1.94	133.20	166.61	1.78	122.61	153.35
41	2.04	3.48	0.03	0.06	0.10	0.19	0.39	0.67	0.46	0.93	1.59
42	108.95	0.00	0.04	4.08	0.00	0.27	29.89	0.00	0.49	53.77	0.00
43	154.61	54.74	0.03	4.38	1.55	0.15	23.91	8.47	0.58	89.65	31.74
Total	1000.00	1000.00		124.92	244.83		957.99	2055.02		1481.10	2219.88

Note: Exports (2) and imports (3) are in million rupees (mrs), and sum to 1 billion rupees. Multipliers in (4) are in 1000 tons of CO_2 per mrs of final demand for commodity *j*. Multipliers in (7) and (10) are in tons of SO_2 and NO_x per mrs of final demand. The pollution in (5) and (6) is in 1000 tons, the pollution in (8), (9), (11) and (12) is in tons.

imports, also trade liberalization in India has led to a further increase of its gains. To this end, we have calculated the ratio of the export to the import related pollution (which should be larger than one for a pollution haven). Together with the volumes of total exports and imports, they are listed in Table III. The results show that an increase of the imports reduces the pollution roughly by twice as much as the increase of the exports (by the same amount) raises the pollution in India. Moreover, the gains of extra trade have clearly increased between 1991/1992 and 1996/1997, in which period the volume of trade increased by more than 50%. So, India was not a pollution haven in the early 1990s and has moved even further away from being a pollution haven in a period of substantial trade expansion.

Closer inspection of the results in Table II shows that the five most important export commodities (Other Services, commodity 43; Other Textiles, 19; Trade, 42; Other Manufacturing, 38; and Rail and Other Transport Services, 40) cover 56% of all exports. In the same way we find that 55% of all imports are concentrated in the top five commodities (Agricultural and Other Non-electrical Machinery, 33; Other Chemicals, 28; Metals and Non-metallic Minerals, 14; Rail and Other Transport Services, 40; and Crude Petroleum and Natural Gas, 2). The three largest multipliers are found for Electricity (commodity 3), Petroleum Products (25) and Fertilizers (26) in case of CO_2 and SO_2, and for Electricity (3), Cement (29) and Iron and Steel (31) in case of NO_x. Most of the largest differences between import related pollution and export related pollution obviously correspond with commodities with a large multiplier and/or a large difference between import and export share. The most notable commodity in this respect is Petroleum Products (25), having the sixth largest import share, a minor export share and outstanding multipliers (by far the largest in case of CO_2 and SO_2, and the fourth largest for NO_x).

It should be emphasized that our analysis is based on the assumption that all the fossil fuels (coal, crude oil and natural gas) are combusted in producing the final demands. That is, in producing the commodities that are

Table III. Ratios of export to import pollution

	1991/1992	1996/1997
Export to import ratios of pollution		
CO_2	0.51	0.42
SO_2	0.47	0.38
NO_x	0.67	0.57
Volumes (in 1991/1992 prices) of		
Exports (in mrs)	557,166	1,022,874
Imports (in mrs)	728,480	1,126,411

used for private and government consumption, that are used as investment goods and that are exported. So, not the final use of the commodities itself generates the emissions, but their production. For almost all commodities this seems to be a plausible assumption, except for commodities such as Petroleum Products. For these products one might argue that combustion takes place when they are actually consumed (either at home as part of private consumption or abroad as part of foreign consumption, which is included in the Indian exports). In particular because Petroleum Products were responsible for a substantial part of the differences between import and export related pollution, it seems reasonable to check to what extent our findings stem from the assumption we have made.

Let us suppose that, in contrast to our earlier assumption, combustion and thus pollution takes place only when the final commodity is used (e.g. consumed). This alternative assumption is made for the following three commodities: Coal and Lignite (1), Crude Petroleum and Natural Gas (2), and Petroleum Products (25). As a consequence, any increase in the exports of these commodities does not change the pollution in India, because pollution takes place abroad when the products are combusted. If total exports increase by 1 billion rupees, the exports of Petroleum Products increase by 19.66 mrs (Table II, column 2, row 25). Satisfying this part of the final demands (directly and indirectly) requires a certain amount of coal and oil. Under the original assumption, the coal and oil is combusted in the production process, which takes place in India. Hence, this yields an increase of 34.09 thousand tons of CO_2 emissions in India (Table II, column 5, row 25). Under the alternative assumption, the increase in the exports of Petroleum Products still requires the same amount of coal and oil. Their combustion, however, occurs only when the product is consumed and for exports this takes place abroad. So, any amount of exports of Petroleum Products does not yield pollution in India. Therefore, we may replace the 34.09 in Table II (column 5, row 25) by 0 under the alternative assumption. The same applies to the values corresponding to the emissions caused by the exports of Coal and Lignite (row 1) and of Crude Petroleum and Natural Gas (row 2).

In the same way, any increase of the imports of e.g. Petroleum Products leaves the pollution in India unchanged. Combustion and pollution take place in India, no matter whether the commodities are imported or produced at home. Again, the results in Table II have to be adapted under this alternative assumption, in the sense that also the import related pollution has to be set at zero, for each of the three commodities (Table II, column 6, rows 1, 2, and 25). The new column totals and ratios under this alternative assumption are given in Table IV.

The major conclusion to be drawn from Table IV, is that the alternative assumption does not change our central finding. That is, India was not a

Table IV. Emission results under the alternative assumption

	1991/1992			1996/1997		
	Export pollution	Import pollution	Ratio	Export pollution	Import pollution	Ratio
CO_2	90.79	121.28	0.75	80.60	111.76	0.72
SO_2	622.03	848.28	0.73	566.86	771.36	0.73
NO_x	1363.40	1758.21	0.78	1156.26	1660.29	0.70

Note: CO_2 emissions are in 1000 tons, SO_2 and NO_x emissions in tons. The increase in total exports and imports is 1 billion rupees (in 1991/1992 prices).

pollution haven in 1991/1992 and the gains from trade were even larger in 1996/1997. Of course, both the export and the import related pollution have been reduced by adopting the alternative assumption. For the three listed commodities, an increase of trade doesn't affect pollution under this alternative, because it no longer matters where production has taken place. It is the final consumption that causes fossil fuel combustion and thus pollution, not the production of these commodities (as was the case under the original assumption). As became already clear in Table II, the alternative assumption decreases import related pollution much more than it does reduce export related pollution. As a consequence, the ratio of export to import related pollution increases substantially, exports being only some 25% less polluting than imports, instead of the 50% in Table II. Also the tendency for the ratio to decrease (i.e. moving further away from being a pollution haven) has diminished. Yet, the ratios are still significantly smaller than one and they still do exhibit a modest decline between 1991/1992 and 1996/1997.

The results sketched by our empirical findings seem to be fairly robust. First, it should be mentioned that in reality none of the two assumptions will be exactly true. Solving this problem would require that for each of the three commodities it would have to be estimated what percentage of pollution is caused by its production and what percentage is caused by its final consumption. If that information were available, the corresponding export to import related pollution ratios would obviously be smaller than those in Table IV but larger than those in Table III. So, the conclusion of India not being a pollution haven during the 1990s would have been unchanged. Second, even if the alternative assumption had been taken into account also for some other commodities, the conclusions would not have been affected. As we have seen in Table II, the gap between import and export related pollution was (for CO_2 and SO_2) by far the largest for Petroleum Products (commodity 25). Precisely this commodity was involved in the alternative assumption. Including other commodities will affect the numerical outcomes, but to a much lesser and to a more balanced extent.

5. Conclusions

In this paper we have examined whether India is a pollution haven. We have calculated by how much the pollution – i.e. CO_2, SO_2 and NO_x emissions – in India will increase if exports are raised by 1 billion rupees, using the actual share of each commodity in total exports. In the same way, it was calculated by how much Indian pollution will fall due to an increase of its imports by 1 billion rupees (using the actual commodity shares in total imports). The emissions will be reduced because the goods that are now imported are no longer produced domestically.

The results showed that the increase in pollution caused by the extra exports is much smaller (roughly half the size) than the decrease in pollution due to extra imports. So, in terms of pollution, India gains from extra trade. According to the pollution haven hypothesis, we would expect that a developing country loses from extra trade, while its trading partner gains. Our findings clearly indicate that the pollution haven hypothesis should be rejected in the case of India. The results also showed that during the 1990s – when trade increased by more than 50% in India – the gains from trade even increased further, indicating that there is no tendency to move towards becoming a pollution haven.

In the introduction, we have discussed that the pollution haven hypothesis may be viewed as a result of the Heckscher–Ohlin (HO) theory, where "emission permits" are taken into account as a third factor. According to the HO model, the country that is relatively abundant in emission permits exports relatively emission intensive goods. So, developing countries are expected to export "dirty" products. Our results show exactly the opposite for India.

About 50 years ago, Leontief (1953, 1956) carried out almost the same exercise to empirically test the HO theory with labor and capital as factors, and found similar surprising results. That is, theory predicts the relatively labor abundant country to export the good that is produced relatively labor intensive and to import the relatively capital intensive good. Leontief calculated that the – direct and indirect – labor and capital requirements necessary to satisfy $1 million of extra exports, were 182.3 worker years and $2.6 million of capital. Replacing a reduction of domestic output by extra imports (to the amount of $1 million) would decrease the requirements by 170.0 worker years and $3.1 million of capital. The US, commonly believed to be the most capital abundant country at that time, was thus found to export labor intensive goods and to import capital intensive goods, however. This result has become known as the Leontief paradox and still continues to trigger ample scientific research.

It should be mentioned that there is one difference between the assumptions underlying Leontief's analysis and ours. Instead of calculating the foreign factor content of US imports on the basis of the foreign input matrix, Leontief estimated this factor content by computing the US factor content (i.e. using the US input matrix) of the domestic production that would replace the US imports. Although Leontief may have been forced to do so because of a lack of data, the procedure is in line with the HO model. In the HO theory, the assumption is made that both trading partners have access to the same technologies. If the factor prices are equalized across countries, this implies that the labor and capital content of US imports can be calculated by using a single – for example the US – input matrix. Recent modifications of the HO model account for technological differences (see, for example, Trefler 1993, 1995; Harrigan 1997). Note that our calculations did not require an explicit assumption and thus allowed for different technologies. The foreign factor (in our case emissions) content of the Indian imports simply is not involved in our analysis. In examining the pollution haven hypothesis, we were interested in the Indian emission content of the domestically produced commodities that are substituted by imported goods, because this substitution reduces production and therefore pollution in India. We have thus not used this Indian emission content to estimate the foreign emission content, which would have required the assumption of identical technologies.

Summarized, given that the pollution haven hypothesis can be viewed as a result of the HO theory, and given that the hypothesis was rejected for India, it seems that this gives rise to a green Leontief paradox. Just as Leontief (1953, 1956) expected the US to export relatively capital intensive goods because it was considered to be a relatively capital abundant country, we expected India to export relatively pollution intensive goods because it is considered to be relatively abundant in terms of “emission permits”. In both cases, the empirical results are exactly the opposite, i.e. the US was found to export relatively labor intensive goods and India relatively “clean” goods. Further empirical studies for other (developing) countries should indicate whether India is an exception or whether the Indian results hint at a general phenomenon. It should be mentioned that – due to data limitations – we have only been able to take a small number of environmental indicators into account. For example, it may well be that the outcome is different if indicators for water pollution or the generation of solid waste are considered.

A possible explanation for the results might be given by the factor endowment hypothesis, which offers another view on the impact of international trade on the allocation of environmental burdens across countries. This hypothesis maintains that pollution intensities of production are highly correlated with capital intensities (see e.g. Copeland and Taylor 2003). In that case, capital-abundant countries (i.e. typically rich, developed countries) have a comparative advantage in pollution intensive goods, which they will export according to the HO theory. A lack of detailed capital-stock data, however, prevents us from further empirically investigating this alternative hypothesis. Yet, the results seem to be more in line with the factor endowment hypothesis than with the pollution haven hypothesis.

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Notes

1. Other commonly discussed impacts are the scale effects (were trade causes an expansion of economic activity and thus pollution) and the technological effects (were trade induces technology spillovers that lead to the adoption of "cleaner" production techniques). See, for example, OECD (1997), Jones (1998), and Nordström and Vaughan (1999).
2. In contrast to the trade-based version of the pollution haven hypothesis that we consider in this paper, the FDI-based version (in which multinationals tend to flock to pollution havens in developing countries) has been tested in Wheeler (2001), Keller and Levinson (2002), Xing and Kolstad (2002), Eskeland and Harrison (2003), Dean et al. (2004), Millimet and List (2004), and Smarzynska Javorcik and Wei (2004).
3. OECD countries account for more than 50% of the trade with India. In particular the European Union (EU15) is an important market for Indian exports, with a share of 20–25%.
4. Input–output techniques have been widely applied to determine the role of international trade in environmental damage. See, for example, Fieleke (1974), Wright (1974), Antweiler (1996), Proops et al. (1999), Lenzen (2001), Machado et al. (2001), Munksgaard and Pedersen (2001), and Kraines and Yoshida (2004).
5. We adopt the usual convention that vectors are columns by definition, so that rows are obtained by transposition, indicated by a prime.
6. Because in India the statistical year starts on March 9, the tables are always indicated by two dates.
7. A "hat" is used to indicate a diagonal matrix. For example, $\hat{\mathbf{z}}$ is the matrix with the elements of the vector $\mathbf{z}$ on its main diagonal and all other entries equal to zero.

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Appendix

Table A1. Commodity classification

1	Coal and lignite
2	Crude petroleum and natural gas
3	Electricity
4	Cereals and pulses
5	Sugercane
6	Jute
7	Cotton
8	Tea and coffee
9	Rubber
10	Other crops
11	Animal husbandry
12	Forestry and logging
13	Fishing
14	Metals and non-metallic minerals
15	Sugar

Table A1. Continued

16	Hydrogenated oil
17	Other food and beverages
18	Cotton textiles
19	Other textiles
20	Wood and wood products
21	Paper and paper products
22	Leather and leather products
23	Rubber products
24	Plastic products
25	Petroleum products
26	Fertilizers
27	Pesticides
28	Other chemicals
29	Cement
30	Other non-metallic mineral products
31	Iron and steel
32	Non-ferrous metals
33	Agricultural and other non-electrical machinery
34	Electrical machinery
35	Communication equipment
36	Electronic equipment
37	Rail and other transport equipment
38	Other manufacturing
39	Construction
40	Rail and other transport services
41	Communication
42	Trade
43	Other services

Table A2. Emissions from one billion rupees of extra exports and imports, 1996/1997

Commodity (1)	Trade		CO_2			SO_2			NO_x		
	Export (2)	Import (3)	Multiplier (4)	Export pollution (5) = (4) × (2)	Import pollution (6) = (4) × (3)	Multiplier (7)	Export Pollution (8) = (7) × (2)	Import Pollution (9) = (7) × (3)	Multiplier (10)	Export Pollution (11) = (10) × (2)	Import Pollution (12) = (10) × (3)
1	0.19	1.54	0.09	0.02	0.14	0.62	0.12	0.95	1.48	0.29	2.27
2	0.00	38.96	0.06	0.00	2.39	0.47	0.00	18.35	0.72	0.00	28.15
3	0.09	0.44	0.52	0.05	0.23	1.88	0.16	0.84	14.35	1.25	6.37
4	7.92	5.94	0.08	0.64	0.48	0.60	4.76	3.57	1.03	8.18	6.14
5	0.00	0.00	0.05	0.00	0.00	0.37	0.00	0.00	0.62	0.00	0.00
6	0.00	0.14	0.01	0.00	0.00	0.09	0.00	0.01	0.16	0.00	0.02
7	9.63	2.01	0.09	0.85	0.18	0.68	6.56	1.37	1.03	9.96	2.08
8	2.70	0.00	0.02	0.06	0.00	0.14	0.38	0.00	0.32	0.86	0.00
9	0.00	0.08	0.04	0.00	0.00	0.28	0.00	0.02	0.47	0.00	0.04
10	41.47	2.91	0.04	1.63	0.11	0.33	13.51	0.95	0.37	15.31	1.07
11	2.18	6.27	0.03	0.06	0.18	0.21	0.46	1.33	0.35	0.76	2.18
12	0.00	8.29	0.02	0.00	0.19	0.20	0.00	1.67	0.17	0.00	1.39
13	17.61	0.07	0.14	2.39	0.01	1.31	23.01	0.10	0.59	10.32	0.04
14	11.38	138.28	0.13	1.44	17.44	0.99	11.25	136.70	1.42	16.11	195.77
15	0.82	0.44	0.08	0.07	0.04	0.64	0.53	0.29	1.03	0.85	0.46
16	0.00	0.20	0.15	0.00	0.03	0.91	0.00	0.18	2.56	0.00	0.52
17	18.54	10.87	0.10	1.84	1.08	0.70	13.05	7.65	1.39	25.86	15.16
18	48.21	0.96	0.13	6.17	0.12	0.74	35.55	0.70	2.47	119.08	2.36
19	141.79	9.17	0.10	14.39	0.93	0.74	105.38	6.81	1.34	190.24	12.30
20	0.28	0.76	0.03	0.01	0.02	0.22	0.06	0.17	0.42	0.12	0.32

Table A2. Continued

Commodity (1)	Trade		CO_2			SO_2			NO_x		
	Export (2)	Import (3)	Multiplier (4)	Export pollution (5) = (4) × (2)	Import pollution (6) = (4) × (3)	Multiplier (7)	Export Pollution (8) = (7) × (2)	Import Pollution (9) = (7) × (3)	Multiplier (10)	Export Pollution (11) = (10) × (2)	Import Pollution (12) = (10) × (3)
21	0.49	16.62	0.17	0.08	2.76	0.86	0.43	14.37	3.57	1.77	59.34
22	66.27	1.15	0.05	3.32	0.06	0.35	22.99	0.40	0.74	49.21	0.85
23	13.50	1.27	0.06	0.84	0.08	0.46	6.16	0.58	0.82	11.05	1.04
24	2.91	0.95	0.06	0.17	0.05	0.41	1.18	0.39	0.82	2.38	0.78
25	10.72	89.26	1.19	12.79	106.49	11.57	124.01	1032.28	4.80	51.43	428.15
26	0.05	24.15	0.32	0.01	7.74	2.41	0.11	58.21	3.99	0.18	96.28
27	2.62	1.84	0.07	0.18	0.13	0.51	1.33	0.94	0.94	2.47	1.74
28	62.24	68.34	0.14	8.87	9.74	1.05	65.33	71.73	1.86	115.74	127.07
29	0.53	0.44	0.27	0.14	0.12	1.16	0.62	0.52	6.78	3.60	3.00
30	3.84	2.27	0.25	0.97	0.58	1.64	6.29	3.71	4.21	16.16	9.55
31	4.33	32.90	0.34	1.46	11.10	1.74	7.53	57.18	7.30	31.62	240.15
32	2.07	14.72	0.28	0.58	4.14	2.04	4.23	30.09	3.77	7.81	55.47

33	28.02	180.55	0.14	3.85	24.83	0.82	23.09	148.75	2.53	70.88	456.64
34	10.80	34.99	0.06	0.62	2.01	0.41	4.48	14.50	0.78	8.45	27.36
35	0.30	7.62	0.06	0.02	0.44	0.41	0.12	3.12	0.83	0.25	6.33
36	32.53	53.39	0.05	1.63	2.68	0.35	11.30	18.54	0.74	24.20	39.71
37	15.45	42.57	0.10	1.47	4.06	0.60	9.25	25.50	1.64	25.35	69.88
38	135.87	26.60	0.08	10.30	2.02	0.46	63.09	12.35	1.36	184.28	36.07
39	0.00	0.00	0.11	0.00	0.00	0.62	0.00	0.00	2.00	0.00	0.00
40	56.10	103.14	0.16	9.03	16.60	1.35	75.61	138.99	1.47	82.50	151.67
41	1.10	4.17	0.03	0.03	0.11	0.17	0.19	0.73	0.39	0.43	1.64
42	169.13	0.00	0.03	5.64	0.00	0.23	38.86	0.00	0.50	83.90	0.00
43	78.30	65.72	0.02	1.78	1.49	0.13	10.02	8.41	0.45	35.16	29.51
Total	1000.00	1000.00		93.41	220.78		690.99	1822.94		1207.98	2118.86

Note: Exports (2) and imports (3) are in million rupees (mrs), and sum to 1 billion rupees. Multipliers in (4) are in 1000 tons of CO_2 per mrs of final demand for commodity *j*. Multipliers in (7) and (10) are in tons of SO_2 and NO_x per mrs of final demand. The pollution in (5) and (6) is in 1000 tons, the pollution in (8), (9), (11) and (12) is in tons.