INTERNATIONAL TRADE AND INDUSTRIAL EMISSIONS IN BRAZIL: AN INPUT-OUTPUT APPROACH[1]

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Abstract

This paper applies input-output techniques to estimate industrial emissions resulting from export oriented activities in Brazil in the period 1985-96. The analysis is based on an input-output model which associates emissions to final demand categories. The emission parameters were extracted from two different data sets. Local pollutant emissions were estimated using the Industrial Pollution Projection System (IPPS, developed by the World Bank), including both water parameters (BOD and heavy metals) and air parameters (particulate matter, SO_2, NO_x and HC). Fossil fuel emissions that contribute to the global warming problem were calculated using CO_2 emission estimates provided by the Brazilian Greenhouse Gases Inventory, covering the 1990-94 period. The input-output matrices were directly obtained from the Brazilian Geography and Statistics Institute (IBGE). Despite the differences between the two sets of emission coefficients, the results in both cases clearly show that export oriented activity chains (considered from an input-output perspective) are more intensive in emissions than the average of the Brazilian economy. This is related to the expansion of resource intensive sectors at the bottom of the export oriented production chains (for example, metallurgy, chemicals, pulp and paper, footwear). Therefore, these results suggest that, at least in the Brazilian experience, there is an association between the efforts to expand exports at any cost (given the balance of payments restrictions) and the worsening of environmental standards, which is another empirical evidence of the hypothesis that developing tend to specialise in "dirty" industrial activities.

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Keywords: pollution, water, air, international trade, industry.

1 Introduction

There is a fierce debate over the pollution consequences of economic policies that favour international trade in developing countries. Critics argue that adjusting countries have more comparative advantages in natural resource based activities, and the pressure to increase the level of exports represent an incentive to the overexploitation of these assets. Since environmental legislation and control in these countries are less strict than in developed countries, this would favour the expansion of pollution and energy intensive industries. One possible outcome of this process is that, in the long term, developing countries would attract investments from pollution intensive industries which have had to 'migrate' from developed countries as a consequence of higher production costs imposed by tighter environmental controls.

At the opposite side, defenders of international trade argue that trade openness brings more production efficiency to the economy. Higher competition would close down companies operating with old and inefficient equipment. Higher prices for energy are an incentive to reduce energy consumption and, therefore, emissions. Finally, the removal of subsidies to capital intensive industries in developing countries would represent an incentive to labour intensive activities, which are less pollutant.

The objective of this paper is to illustrate this debate in the context of the Brazilian economy in the period 1985/94. During this period, there was a considerable expansion of export-oriented activities as called for by the adjustment principles adopted by Brazilian policy-makers. More precisely, this paper investigates whether the shift towards an export oriented industrial growth has influenced the pollution problem in Brazil. The methodology is based on the combination of input-output techniques and the use of pollutant emission coefficients, estimated according to actual data for Brazil.

The results are divided in two groups. The first one refers to the emission of pollutants that affect the local environment: biochemical demand for oxygen (BOD) and heavy metals for water pollution, and particulate matter, sulphur dioxide (SO_2), nitrogen oxides (NO_x) and hydrocarbons (HC) for air pollution. These parameters are considered for the year 1985, according to emission coefficients originally estimated by Serôa da Motta *et al.* (1993, 1996) and Mendes (1994). The second group refers to carbon dioxide (CO_2), the most import gas connected to the greenhouse effect. Emission coefficients are estimated according to recent data on carbon emissions from fossil fuel consumption in the 1990/94 period, prepared by COPPE/UFRJ. Both groups of results indicate that the export oriented activities are the most intensive in emissions. Also, in the 1990/94 period, carbon emissions increased steadily. This suggests that the structural changes in the Brazilian economy in the period, associated with the adjustment objective of increasing the share of Brazilian exports in the world trade, encouraged industries which are more intensive sources of emission.

2 Export promotion policies and pollution in Brazil

The Brazilian economy has experienced successive policy changes to alleviate the pressure on the balance of payments caused by external debt crisis. In the early 1980s, in order to improve the external accounts situation, many incentives were created to increase exports. Indeed, the expansion of the export sector was a key element in the structural adjustment strategy carried out with the approval of the IMF and the World Bank. This change in the orientation of the industrial policy, so far dedicated to import-substitution, has affected considerably the Brazilian industrial structure. As a consequence, the export oriented industries achieved a much better performance relative to the traditional, domestic market oriented industries.

In the late 1980s and, even more in the 1990s, the economy went through a stop-and-go cycle characterised by the expansion of imports, following trade liberalisation policies adopted more aggressively by each successive government in the period. This trend of imports expansion was particularly accentuated with the exchange rate overvaluation after the Real stabilisation programme in 1994. As a consequence, in many production chains there was a strong expansion in the use of imported inputs, and the subsequent reduction in the use of domestic ones. Two direct consequences of this process were unemployment and decreasing output in many industrial sectors, and increasing trade deficit.

During the same period, there is evidence that the pollution problem has increased in Brazil. Carvalho and Ferreira (1992) created an index of industrial growth according to four groups of potential pollution impacts: high, moderate, low and negligible. The index was built using output data from IBGE's monthly industrial survey, combined with the air and water pollution potential of each product according to the classification adopted by the state of Rio de Janeiro environmental agency (FEEMA). It is important to highlight that FEEMA's classification is based on the potential hazard of the production of the good to the air or water assuming that no mitigation measures are taken. Therefore this index does not consider the existence of abatement processes which may reduce or even eliminate the pollution impact. In other words, it is an estimate of potential rather than actual industrial pollution.

Table 1 and graph 1 present the results obtained by Carvalho and Ferreira (1992). They show that the industries with high and moderate pollution potential grew at higher rates than the average of the Brazilian industry. The worst performance refers to the industry with negligible pollution potential. The conclusion of the study was that the dynamics of industrial growth in the Brazilian industry since the 1980s has been positively associated with the level of potential pollution: the higher the growth, the higher the pollution threat, in a way that industrial growth has been diverted towards the potentially polluting industries.

Table 1. Brazilian industry evolution according to its pollution potential (1981=100)

Year	High	Moderate	Low	Negligible	Total
1982	101.9	102.9	92.9	103.3	100.0
1983	100.1	96.6	83.4	93.3	94.8

1984	107.9	102.6	89.9	97.2	101.6
1985	115.8	112.5	99.4	104.5	110.2
1986	123.6	129.1	120.8	114.0	122.3
1987	125.5	128.7	123.8	106.3	123.3
1988	125.4	123.7	113.5	97.4	119.3
1989	127.3	127.8	119.5	102.9	122.8
1990	119.1	116.6	104.1	90.1	112.9
1991	120.7	118.3	98.7	83.9	112.3
1992	118.8	110.1	87.8	77.5	107.1

Source: Carvalho and Ferreira (1992)

Figure A Evolution of the Brazilian industry according to its pollution potential (1981=100)

Source: Carvalho and Ferreira (1992)

According to the adjustment debate, the simultaneity of the expansion of the export oriented industrial sector and the increase in the levels of pollution may suggest that developing countries under adjustment programmes, such as Brazil, tend to specialise in polluting industries due to their lower costs to conform to environmental standards (compared with the same costs in developed countries). On this view, the expansion of the potential levels of pollution is not a coincidence but a consequence of the boom in export oriented activities.

However, since the exercise carried out by Carvalho and Ferreira (1992) is based on potential rather than actual data, it is not possible to refute the opposite proposition, i.e. the change in the structure of the industry was environmentally beneficial. One possible explanation is that export oriented industries need to be more efficient in order achieve international competitiveness, and modern technology tends to be less polluting. These higher efficiency standards may have resulted in better environmental practices which were not captured by the exercise.

This paper provides an empirical test if this emission trend happened in terms of carbon emission, the most important factor for global warming. It follows an input-output methodological approach that considers the whole production chain necessary to achieve a certain final demand vector (consumption, investment and exports), described in the next section.

3 Industrial emission: an input-output model

3.1 The input-output model

The objective of the input-output model is to describe the interdependence of the economy, given the current levels of production and consumption. Assuming that all the (n) sectors of an economy keep a constant share in the market of each product, and that the production processes of all these sectors are technologically interdependent and characterised by a linear relation between the amount of inputs required and the final output of each sector, it is possible to obtain a system containing *n* equations relating the output of every sector to the output of all other sectors. The model also considers an autonomous sector (final demand) which is determined exogenously to the model. The sales of each sector should be equal to autonomous consumption (related to the categories of final demand) plus the amount of production destined to the intermediate consumption of all the other sectors (Dorfman, 1954).

In formal terms:

$$x_i = \sum_{j=1}^{n} x_{ij} + C_i + I_i + G_i + Ei - Mi \qquad \textbf{(A)}$$

where x_{ij} is the amount of output from sector i demanded as intermediate consumption to sector j, and C_i, I_i, G_i, E_i, M_i and x_i are, respectively, the private consumption, investment, public administration consumption, exports, imports and domestic production of sector i (Prado, 1981).

The basic assumption is that the intermediate consumption is a fixed proportion of the total output of each product:

$$x_i = \sum_{j=1}^{n} a_{ij} \cdot x_j + d_i \qquad \textbf{(B)}$$

where a_{ij} is the technical coefficient determining the amount of product of sector i required for the production of one unit of product in sector j, and d_i is the amount of final demand for products from sector i ($d_i = C_i + I_i + G_i + E_i - M_i$).

In matrix terms, this is expressed by:

$$x = Ax + d \quad \textbf{(C)}$$

where x is a nx1 vector with the total product of each sector, d is a nx1 vector with sectoral final demand, and A is a nxn matrix with the technical coefficients of production.

Since the final demand is exogenously determined, the intermediate consumption can be obtained by the following equation:

$$x = (I - A)^{-1} d \quad \textbf{(D)}$$

where $(I - A)^{-1}$ is the nxn matrix containing the input-output coefficients for the relations between sectors.

The same formula is valid for calculating the direct and indirect effects of exports or any other component of the final demand, instead of its aggregate:

$$x_f = (I - A)^{-1} d_f \quad \textbf{(E)}$$

where x_f is the nx1 vector containing the total production per sector necessary to obtain the nx1 vector of the f-category of final demand (d_f).

Therefore, the input-output model allows the determination of the level of economic activity in each productive sector as a function of the final demand for each product.

3.2 Introducing emission coefficients

The use of extended input-output tables to estimate emissions and other discharges of residuals has become an important instrument to assess environmental problems at the macroeconomic level (for a review, see Førsund, 1985; the methodology adopted in this section is based on Pedersen, 1993). The most common procedure is to assume that emissions are linearly related to the gross output of each sector, in a way that each industry generates residuals in fixed proportions to the sector output. The emission coefficient of pollutant h by sector i (ef_{hi}) can be obtained by dividing the total emission of a sector (em_i) by the total output of the same sector (x_i):

$$ef_{hi} = \frac{em_{hi}}{x_i} \qquad \textbf{(F)}$$

Given this assumption, it is possible to obtain the total emission caused by the f-category of final demand through the use of emission coefficients for each sector. In formal terms, this is expressed by:

$$z_{hf} = diag(ef_h).x_f = diag(ef_h).(I - A)^{-1} d_f \qquad \textbf{(G)}$$

where z_{hf} is the nx1 vector containing the total emission of pollutant h per sector associated to the f-category of final demand, and diag(ef_h) is the nxn matrix containing in its principal diagonal the emission factors of pollutant h for each sector, and zeroes elsewhere (Pedersen, 1993).

4 Application to Brazil

This section describes the procedures used to calculate equation 7 for the Brazilian economy, combining the input-output tables (42x42 activities) prepared by the Brazilian Institute of Geography and Statistics (IBGE) and the emission coefficients, local and global.

4.1 Local pollutants

The emission of local pollutants was calculated using the results from empirical studies carried out by the Environmental Economics Research Division at IPEA (Serôa da Motta *et al.*, 1993; Mendes, 1994; Serôa da Motta, 1993a, 1993b, 1996). These studies estimated the effectiveness of abatement policy and the status of current water and air industrial pollution in Brazil, based on indicators of water and air quality for 13 states where systematic monitoring is undertaken.[2] This database was built using pollution emission and abatement estimates for the year 1988 according to a World Bank funded project denominated PRONACOP (Brazilian National Programme of Pollution Control), covering 12 states, plus similar information for the state of São Paulo for the year 1991, using data from the state's environmental agency (CETESB). The parameters considered were biochemical oxygen demand (BOD) and heavy metals for water pollution, and particulate matter, sulphur dioxide (SO_2), nitrogen oxides (NO_x), and hydrocarbons (HC) for air pollution.

The estimates of potential emissions were obtained by multiplying the potential output of every industrial establishment registered at the states' environmental agencies by emission parameters obtained from the technical literature (mostly taken from World Health Organisation). The potential pollution emissions estimated this way were considered as a measure of the level of pollutant emitted by the industrial establishment without any treatment.

Data on actual emissions proved to be scarce and, in some cases, available but not reliable (Mendes, 1994). Therefore, the level of actual pollution was estimated by an abatement indicator which considered the potential for emission treatment at the source point (i.e. every industrial establishment registered in the database). The indicators of potential and actual pollution were then divided by the value added of the respective industrial sectors,

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2 These 13 states combined were responsible for 96% of the Brazilian manufacturing industrial output according to the 1985 Industrial Census.

at the state level, in order to produce the pollution intensity coefficients. Tables 2 and 3 present the average value for the 13 states.

Table 2 Water pollution: potential and actual pollution intensity coefficients, by industrial sector (g/US$ of value added), Brazil, 1988

Industrial sector	Biochem. Oxygen Demand		Heavy Metals	
	Potential	Actual	Potential	Actual
Metallurgy	1.12	0.04	1.73	0.85
Mechanical	0.73	0.60	0.16	0.07
Transport equipment	0.49	0.18	0.13	0.05
Wood products	19.83	8.82	0.00	0.00
Paper & cellulose	37.35	12.91	0.00	0.00
Chemicals	86.85	16.15	0.03	0.03
Drugs & medicine	2.25	1.47	0.00	0.00
Cosmestics & soap	7.02	4.58	0.00	0.00
Textiles	7.11	4.40	0.00	0.00
Leather & footwear	45.36	21.69	1.84	0.76
Food products	27.96	11.31	0.00	0.00
Beverages	105.11	40.98	0.00	0.00

Source: Mendes (1994)

Table 3. Air pollution: potential and actual pollution intensity coefficients), by industrial sector (g/US$ of value added), Brazil, 1988

Industrial sectors	Partic. matter		SO_2		NO_X		HC	
	Potent.	Actual	Potent.	Actual	Potent.	Actual	Potent.	Actual
Non-metallic minerals	689.1	261.4	51.2	51.0	10.9	10.9	0.2	0.2
Metallurgy	247.0	111.4	50.7	50.7	17.2	17.2	6.2	6.2
Mechanics	5.8	1.1	1.3	1.3	0.1	0.1	2.0	2.0
Electric materials	0.4	0.1	0.2	0.2	0.0	0.0	2.2	1.6
Transport equip.	0.4	0.1	0.2	0.1	0.0	0.0	0.6	0.5
Wood products	42.2	42.1	2.5	2.5	9.7	9.7	2.9	2.9
Paper & cellulose	133.8	28.2	16.0	15.8	32.5	32.5	0.7	0.7
Rubber products	0.4	0.4	3.3	3.3	0.5	0.5	0.1	0.1
Chemicals	41.4	18.3	61.4	59.9	45.7	45.6	38.8	18.4
Drugs & medicine	0.4	0.4	2.0	1.9	5.5	5.5	0.1	0.1
Comestics & soap	8.8	4.5	32.3	32.3	2.9	2.9	0.1	0.1
Textiles	26.4	24.3	13.8	13.4	11.2	11.2	0.4	0.3
Leather & footwear	1.0	0.9	5.5	5.5	0.7	0.7	0.7	0.7
Food products	27.5	21.8	72.5	72.5	8.8	8.8	0.2	0.2
Beverages	68.1	58.2	35.7	35.7	17.4	17.4	0.4	0.4

Source: Serôa da Motta *et al.* (1993)

One adaptation was required because the above emission coefficients were based on the value added (VA) in each industrial sector. However, equation 7 refers to the total value of production (VP), including the intermediate consumption required. Therefore, the VA-based emission coefficients were multiplied by the VP/VA ratio for each industrial sector, in order to provide VP-based emission coefficients which could be applied to the direct and indirect effects of each category of final demand.

The aggregate contribution of each category of final demand to the value of production, according to the IBGE tables, is presented in tables 3 and 4. Table 5 presents the estimated emission of pollutants required in the production chain resulting from each category of final demand, according to equation 7. Table 6 shows the results as a proportion of the total emission of each pollutant. Finally, table 7 presents the pollution intensity in the total production resulting from each category of final demand, i.e. the ratio between the total emission and the value of production of each category of final demand.

Table 4. Total output directly or indirectly related to the categories of final demand, Brazil, 1985

Category	1985 US$ Millions	% of total output
Exports	54,774	14.2%
Investment*	90,502	23.4%
Public administration	42,216	10.9%
Private consumption	199,423	51.5%
Total	386,916	100.0%

* Investment includes changes in stocks

Table 5. Total (actual) emissions caused by final demand, 1,000 t, Brazil, 1985

Parameters	Exports	Investment	Public administration	Private consumption	Total
Water emissions (1000 t)					
BOD	110,964	70,376	18,645	395,096	595,080
Heavy metals	3,162	3,692	185	3,704	10,743
Air emissions (1000 t)					
Partic. matter	561,212	1,205,839	67,282	1,037,977	2,872,311
SO_2	482,826	510,080	59,034	1,035,496	2,087,436
NO_X	239,529	230,225	41,850	541,549	1,053,152
HC	82,837	80,893	10,798	158,846	333,375

Table 6. Total (actual) emissions caused by final demand (%), Brazil, 1985

Parameters	Exports	Investment	Public administration	Private consumption	Total
Water emissions (1000 t)					
BOD	18.6%	11.8%	3.1%	66.4%	100.0%
Heavy metals	29.4%	34.4%	1.7%	34.5%	100.0%
Air emissions (1000 t)					
Particulate matter	19.5%	42.0%	2.3%	36.1%	100.0%
SO_2	23.1%	24.4%	2.8%	49.6%	100.0%
NO_X	22.7%	21.9%	4.0%	51.4%	100.0%
HC	24.8%	24.3%	3.2%	47.6%	100.0%

Table 7. Pollution intensity per unit of output (g/US$), Brazil, 1985

Parameters	Exports	Investment	Public administration	Private consumption	Total
Water emissions (1000 t)					
BOD	2.608	0.666	0.581	1.841	1.507
Heavy metals	0.074	0.035	0.006	0.017	0.027
Air emissions (1000 t)					
Partic. matter	13.188	11.414	2.096	4.837	7.274
SO_2	11.346	4.828	1.839	4.825	5.286
NO_X	5.629	2.179	1.304	2.524	2.667
HC	1.947	0.766	0.336	0.740	0.844

It can be seen from tables 5, 6 and 7 that the proportional contribution of exports to the total emission of all pollutants exceeded the contribution of exports to the total output (14.2%). In other words, exports are more pollution-intensive than the average of the economy. This problem is particularly important for heavy metals, carbon monoxide and hydrocarbons, where the difference between the contribution to the total emission and the total value of production exceeds 10%.

The same problem is reflected in the intensity coefficients: for each pollutant, the amount of emission required to produce one unit of export related output exceeds the average of the economy. Indeed, the intensity of pollution is higher in export related activities than in any other group for the two water pollution parameters and for three of the four air pollution parameters (SO_2, NO_x, and HC).

In sectoral terms, it is clear that a few sectors account for most industrial water and air pollution. Most of these 'dirty' industries are related directly or indirectly to export oriented activities, such as metallurgy (input for the motor car industry and other industrial export goods), paper and cellulose and footwear (leather products). The most important pollutant industries are: chemicals, food products and paper and cellulose for BOD; metallurgy for heavy metals; non-metallic minerals and metallurgy for particulate matter; chemicals, metallurgy and non-metallic minerals for SO_2; chemicals, metallurgy, paper and cellulose, and food products for NO_X; and chemicals for HC.

4.2 Carbon dioxide

A recent study by COPPE/UFRJ (1998) estimated CO_2 emissions from fossil fuel consumption in Brazil in the period 1990/94. Table 8 presents the main results.

Table 8. CO_2 emissions from fossil fuels consumption, Brazil (1990/94)

Sector	1990		1991		1992		1993		1994	
	Gg CO_2	%	Gg CO_2	%	Gg CO_2	%	Gg CO_2	%	Gg CO_2	%
Energy	13226,3	7,3	11875,2	6,3	12462,4	6,5	13471,4	6,7	13954,0	6,6

Residential	13767,5	7,6	14140,6	7,4	14650,2	7,6	15184,1	7,5	15188,4	7,2
Commercial & Public	2546,4	1,4	2428,0	1,3	2458,0	1,3	2411,6	1,2	3523,9	1,7
Agriculture	9997,8	5,5	10425,5	5,5	10726,2	5,6	11851,1	5,9	12516,4	5,9
Industrial	59850,3	33,2	65771,8	34,7	66635,1	34,6	69839,0	34,6	72272,2	34,3
Transport	81142,2	44,9	85165,7	44,9	85807,6	44,5	89214,8	44,2	93331,3	44,3
Total	180530,5	100,0	189806,9	100,0	192739,5	100,0	201972,1	100,0	210786,2	100,0

Source: COPPE (1998)

The aggregate contribution of each category of final demand to the total value of production is presented in table 9. Again, the results were obtained through the use of the Leontief input-output table, according to equation 5.[3]

Table 9. Total output directly or indirectly related to the categories of final demand, Brazil 1990/94 (R$ 1994)

Year	Exports	Consumption*	Investment	Total	Annual change (%)
1990	53952343	386445965	111067317	551465625	
1991	56287643	381007317	104932863	542227824	-1,7%
1992	70932911	379687193	97240743	547860847	1,0%
1993	71865186	400943300	110301814	583110299	6,4%
1994	68304828	411649994	120238226	600193049	2,9%
Change 94/90(%)	26,6%	6,5%	8,3%	8,8%	

[3]These results are not directly comparable to those presented in table 4 because of methodological chnages in the estimation of oil prices between 1985 and the series starting in 1990. In 1985, oil prices were considered as the production values given by Petrobrás, but since 1990, the border price has been used instead. Since the former is higher than the later, and that the export chain is considerably more intensive in oil than the rest of the economy, the output value of the export complex in 1985 is overvalued if compared to the other years.

Table 10 presents the estimates of CO_2 emissions from fossil fuels in each production chain. The estimation procedure was based on the data from table 8, classified according to economic sectors. The emissions from the residential sector were excluded from the exercise because they were considered as not being demanded by any production sector.

Table 10. CO_2 emissions associated with production chains, 1990/94 (Gg CO_2)

Year	Exports	Consumption*	Investment	Total	Annual change (%)
1990	34193	101986	30585	166765	
1991	39515	103004	33149	175667	5,3%
1992	45166	104304	28619	178090	1,4%
1993	43657	111898	31233	186788	4,9%
1994	43347	115869	36381	195598	4,7%
Change 94/90(%)	26,8%	13,6%	19,0%	17,3%	

Finally, table 11 presents the intensity coefficients (CO_2 per unit of output) in each production chain:

Table 11. Emission intensity per unit of output (tCO_2/R$ 1994)

Year	Exports	Consumption*	Investment	Total	Annual change (%)
1990	0,634	0,264	0,275	0,302	
1991	0,702	0,270	0,316	0,324	7,1%
1992	0,637	0,275	0,294	0,325	0,3%
1993	0,607	0,279	0,283	0,320	-1,5%
1994	0,635	0,281	0,303	0,326	1,7%
Change 94/90(%)	0,1%	6,7%	9,9%	7,8%	

The tables above clearly indicate that, in every year considered, the relative contribution of the export complex to CO_2 emissions were always around twice the equivalent value of their contribution to total output. In other words, the production of export goods and respective inputs is considerably more emission intensive than in the other chains. Even though the intensity of CO_2 per output unit remained relatively stable (while it increased in the rest of the economy), the higher growth in output lead to an almost identical increase in emissions (27%), well above the average growth for the whole economy (17%). This is another strong evidence that, in the first half of the 1990s, the Brazilian economy continued its process of trade specialisation in “dirty” activities.

In sectoral terms, again, most of the emissions are concentrated in a few number of 'dirty' activities, directly or indirectly related to exports: metallurgy, chemicals, agriculture (the high increase in agricultural emissions is a consequence of the mechanisation process, resulting in more fuel consumption) and the transportation sector.

On the other hand, despite the accelerated growth in imported goods, the average emission intensity increased (more emissions required to produce the same amount of output). Therefore, the empirical evidence goes against the hypothesis that free trade and capital flows would lead to higher efficiency in environmental standards.

4.3 Methodological limitations

It is important to bear in mind the many limitations involved in these exercises. Firstly, pollution estimates were not directly obtained from observations of water and air quality but indirectly, by the specifications of the industrial plants surveyed. The environmental impact of a specific pollutant is affected by many other variables which were not considered in the exercise. Secondly, a linear relationship is assumed between output and emissions - in reality this relationship is far more complex. Thirdly, it is very likely that the total amount of emission was underestimated. This point would be important in the case of sectors where a very large number of only marginally pollutant establishments are responsible for a considerable amount of the total pollution. Given these limitations imposed by the lack of more reliable data on industrial pollution in Brazil, the results from this exercise should be considered as a preliminary attempt to assess the contribution of export oriented activities to the air and water pollution problems in Brazil. Nevertheless, the consistency of these results with other empirical studies on the same issue (Veiga *et al.* 1995, Torres *et al.* 1997), but with a less aggregate perspective, is a strong element in favour of the conclusions obtained in this study.

5 Conclusion

Brazil undertook structural changes in its economy since the 1980s. These changes resulted in the removal of domestic distortions and in the increase of international trade (both exports and imports), as preached by the international development agencies and most of the governments of developed countries. However, many of the benefited sectors were emission intensive, particularly the ones at the bottom of the chain of export oriented activities (metallurgy, chemicals). The final effect was an overall increase of the emission intensity of the industrial output, led by the export sector.

Therefore, these results suggest an association between the options left to developing countries to improve their share in the international trade and the deterioration of environmental standards. If no alternatives are left, developing countries will be forced to deepen their fight for direct investment inflows that may conceal the migration of “dirty” industries undesired by developed countries.

At the same time, nevertheless, there is an increasing pressure on developing countries to avoid the uncontrolled growth of their emissions of greenhouse gases. This point was made clear in the Kyoto Conference (December 1997) by the position of some developed countries (particularly the United States of America) that would only accept binding restrictions in their own emissions if some kind of control is also imposed on developing countries' emissions.

The contradiction of this situation is clear. On the one hand, developed countries want to establish effective reductions in greenhouse gases emissions, and therefore they are willing to impose restrictions on pollution activities in their own territory. On the other hand, however, economic circumstances force developing countries to beg for foreign direct investment that is mainly looking for the (static) comparative advantages in these countries - usually, their natural resources abundance or inexpensive labour - and, in many cases, in a predatory way: the cheaper, the better. Environmental restrictions are unlikely to be imposed on these capital inflows, especially if the effects are not local but global, and it is very likely that the benefits of emission reduction in developed countries are swapped for higher emissions in the Third World.

Therefore, the environmental problems can not be dissociated from the economic questions which underlie them. Sustainable development strategies for the global warming problem must consider instruments (such as the Clean Developed Mechanism proposed in Kyoto) which connect both sides of the story.

A final comment refers to greenhouse emissions from deforestation. These were not included in this work, even though they still represent the most important source of Brazilian emissions. One major issue refers to the paths opened in the forest by loggers directly or indirectly related to exporters. These paths represent a major incentive for the agricultural occupation of the land. Another link concerns the expansion of tradable crops in frontier land: the boom of agricultural activities caused by export opportunities lead to land price appreciation, creating an important economic incentive to the conversion of forest land into cultivation. An analysis of the complex social and economic dimensions of the conversion of land through slash-and-burn practices goes beyond the objective of this paper, but it is definitively connected to the international trade issue - a detailed analysis is presented in Young (1996).

References

BRASIL, MINISTÉRIO DE MINAS E ENERGIA. *Balanço Energético Nacional 1997*.

CARVALHO, P.G.M.; FERREIRA, M.T. Poluição e crescimento na década perdida, *Políticas Governamentais*, v.80, May/Jun.,1992, p.10-12.

COPPE/UFRJ. *Inventário de emissões de gases de efeito estufa - sistema energético. Relatório: determinação das emisões de carbono derivadas do sistema energético brasileiro - abordagem bottom-up*. Rio de Janeiro: COPPE/UFRJ, 1998.

DORFMAN, R. The nature and significance of input-output, *Review of Economics and Statistics* v.36, May, 1954.

FØRSUND, F.R. Input-output models, national economic models, and the environment, in: KNEESE, A.V.; SWEENEY, J.L. (eds.). *Handbook of natural resource and energy economics*, v.I . Amsterdam: Elsevier, 1985.

IBGE. *Matriz de insumo-produto 1980*. Rio de Janeiro: IBGE, 1989 (Discussion Paper 14).

____. *Matriz de insumo-produto Brasil - 1985*. Rio de Janeiro: IBGE, 1995.

MENDES, F.E. *Uma avaliacão crítica dos custos de controle dapoluição hídrica de oriem industrial no Brasil*. Tese de Mestrado, Rio de Janeiro: COPPE/UFRJ. 1994.

PEDERSEN, O.G. *Input-output analysis and emissions of CO_2SO_2, and NO_x - the linkage of physical and monetary data*. (Paper presented at the Tenth International Conference on Input-Output Techniques). Sevilla, March 29-April 2, 1993.

PRADO, E. *Estrutura tecnológica e desenvolvimento regional.* Estudos Econômicos, v.10. São Paulo: IPE/USP, 1981.

SERÔA DA MOTTA, R. *Política de controle ambiental e competitividade - estudo da competitividade da indústria brasileira.* Campinas: IE/UNICAMP-IE/UFRJ-FDC-FUNCEX, 1993.

____. *Indicadores ambientais no Brasil: aspectos ecológicos, de eficiência e distributivos*. Rio de Janeiro: IPEA, 1996. (Texto para Discussão 403).

SERÔA DA MOTTA, R. *et alli. Uso de instrumentos econômicos na gestão ambiental da América atina e caribe: lições e recomendações*. Rio de Janeiro: IPEA, 1996. (Texto para Discussão 440).

VEIGA, P.M., CASTILHO, M.R., FERRAZ FILHO, G. 1995. *Relationships betwen trade and the environment: theBrazilian case*. Rio de Janeiro, FUNCEX, 1995. (Texto para Discussão 93).

TORRES, H.G. *et alli.* “Estrutura industrial e impactosambientais: um estudo das empresas siderúrgicas e da poluição hídrica na bacia do rio Piracicaba (MG)”, *Nova Economia*, special issue, 1997.

YOUNG, C.E.F. *Economic Adjustment Policies and the Environment: A Case Study of Brazil*. PhD Dissertation, University College London, 1996.

____. *Industrial polllution and export-oriented policies in Brazil*. Rio de Janeiro: IE/UFRJ (Discussion Paper 383), 1997.