Environmental regulation and competitiveness in Brazilian industry, with special reference to the energy sector

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January – July 2002

Oxford – BP Brasil
Research paper number 2

Centre for Brazilian Studies
University of Oxford
June 2003

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1. Introduction

This paper examines the behaviour of Brazilian industrial firms in response to environmental regulation, theoretically and empirically, with special reference to the oil and natural gas sectors. Chapter 2 summarises the arguments and counter-arguments in current debates on competitiveness and environmental regulation. Chapter 3 analyzes the environmental performance of Brazilian industry, arguing that a trend towards specialisation in products with relatively high pollution potential has occurred. Chapter 4 focuses on the diffusion of clean technologies, arguing that a series of firm-specific and sector-specific characteristics such as size, capital ownership and market structure affect this process of specialization in Brazil. Chapter 5 takes a closer look at the oil and gas sectors, presenting estimates of natural resource depletion and pollution in Brazil, and examining trends in environmental regulation within the sector. Chapter 6 presents the main conclusions and policy recommendations. The Appendix reviews the evolutionary economics literature and the application of the debate on innovation and competitiveness to explain the diffusion of clean technologies.

2. Environmental regulation and competitiveness: the current debate

What are the effects of measures of environmental protection on a firm's competitiveness? This is an on-going debate that has important implications for policymaking. On the one hand, there is deep scepticism among environmentalists about the consequences of economic policies that promote production and trade, particularly in the industrial sector. This issue is connected to a broader rejection of what has been referred to as "the Washington consensus," a set of policy recommendations (primarliy privatisation of state firms and liberalization of trade) that seeks to stabilize prices, improve trade balances, and reform the role of government in the economy, reducing the range of its activity but making policies more efficient.

These policy guidelines that combe openness, efficiency, and austerity are largely macroeconomic, but sectoral programmes also receive special attention. In this respect, the removal of subsidies and the elimination of import restrictions are considered instruments to increase efficiency and competitiveness. Less competitive sectors may suffer, but overall economic growth is expected, particularly in the export sector.

Criticisms of these policies can be arranged in two main groups:

a) The stagnation hypothesis: many consider that these economic reforms do not promote growth, especially in developing countries. Instead, they lead to economic stagnation.[1] And because recessions increase poverty, these measures lead to the depletion of open-access resources in the rural environment, while encouraging exodus to shantytowns and slums in urban areas, where the population becomes more vulnerable to pollution problems. Cutbacks in government spending also seem to affect environmental and other welfare-related expenditures.[2] Thus, while stabilisation may offer short-term relief from some resource management problems, it can also create or aggravate other environmental problems through its effect on poverty and dependence on natural resources, mainly in the external sector. In sum, from this perspective, depletion and degradation are the hidden cost of increasing exports.

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[1] See Stiglitz (2002) for a summary of the main criticisms that are presented to the macroeconomic approach of the International Monetary Fund (IMF) and, in more generalterms, to the "Washington consensus".

[2] This is, indeed, the main result of a series of studies carried out by the Economic Comission for Latin America and the Caribbean (ECLAC) in eight different countries. See Schapper (2002) for a summary of the results, and Young & Roncisvalle (2002) for the Brazilian case.

b) The growth hypothesis: in this case, the problem is a consequence of the success, rather than the failure, of the economic reforms. The main assumption is that economic growth leads to more environmental degradation because increased production and consumption mean more demand for natural resources and more emission of pollutants. This tension between economic and environmental objectives is greater in developing countries, because their comparative advantages in natural resources means that free trade strategies would enhance their expansion. Since environmental regulations in these countries are less strict than in developed countries, this also favours the growth 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 that flee developed countries and the higher production costs imposed by tighter environmental controls.

On the other hand, defenders of economic reform argue that free trade and capital flows bring more efficiency to the economy because of the following reasons:

a) Higher competition closes down companies operating with old and inefficient equipment. These are the companies with higher probability of being environmentally harmful, either because of old machinery/technology, or waste in production processes. A more competitive atmosphere would force firms to adopt contemporary production processes, which tend to be more efficient in all aspects including the environmental (in terms of emission avoidance and raw materials savings).

b) Eliminating subsidies or other incentives for energy-intensive sectors acts as an incentive to reduce energy consumption and, therefore, emissions and pollution. These sectors tend also to be capital intensive, and according to the theory of comparative advantages, free trade policies would favour a shift in developing countries towards labour-intensive activities, which tend to be less polluting.

c) The reduction of trade barriers favours the import of modern, state-of-the-art equipment. Since imported machinery meets tougher environmental standards in developed countries, its acquisition can improve the environmental performance of the developing country.

d) Consumers in developed countries are increasingly concerned about the environmental standards of the products they buy. This has forced the adoption of environmentally friendly production patterns, certified by green labels, for those willing to export to these markets. The demonstration effect then leads to this behaviour being adopted by producers aiming at the domestic market, and local consumers become more aware of the environmental implications of production and consumption of the products they buy.

To understand the difference between those who complain about trade and those who do not, it is crucial to bear in mind that most of these analytical studies are not based on historical/empirical analysis, but are deeply rooted in theoretical arguments derived from idealised models of reality (which, again, are strongly related to ideological positions). The document on international trade and the environment issued by the World Trade Organisation (WTO 2000) is a good example of the belief that, under "ideal" circumstances, promoting free market is always the best policy:

> "In the best of all worlds, governments would use proper environmental policies to 'internalise' the full environmental costs of production and consumption - the 'Polluter Pays Principle'. (...) In this idealised world, trade liberalisation would unambiguously raise welfare" (WTO 2000, p.2)

The conclusion of this argument appear to be simply a consequence of the fact that problems are eliminated by the construction of an idealised world according to the beliefs of an ideology - in this case that of free markets. The "ideal world" is so precisely because it is the best application of that set of beliefs.[3] Nonetheless, this kind of argument is repeatedly used by governments and multilateral development agencies in their justification to deepen reforms towards more openness (for a critical analysis of the environmental consequences of adjustment policies, see Young 1997). Moreover, once problems are identified with the implementation of reform policies, it is usually considered not a fault of the policy itself but a "failure" of the real economy, in the sense that it does not behave according to the "perfect" world proposed by theory. It follows that even more reforms are needed in order to turn the real world "more perfect" - i.e., closer to the idealised theoretical model.

Once more realistic assumptions are made, even neoclassical theoretical models present results showing that improving trade relations may result in damages to the environment. Three counter-arguments are commonly used to justify a change in the current regulatory framework concerning international trade that disallowed restrictions justified by environmental (WTO 2000):

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[3]The same kind of "conclusion" is easily obtained if one uses the argument of the "idealized" world according to a theoretical model different from the proposed free market. For example, in an idealized world according to the Marxist-Leninist theory, any improvement towards more socialism (against almost all pro-market proposals) will unambiguously lead to raising welfare.

a) The legal argument: existing rules provide legal cover for foreign countries to challenge domestic environmental policies that interfere with their trading rights.

b) The political economy argument: the competitive pressure from the world market sometimes makes it impossible to forge the necessary political support at home to upgrade environmental standards.

c) The market failure argument: in the existing institutional conditions of developing countries, international trade may magnify the effects of poor environmental policies in the world (increasing the tendencies of overexploitation of natural resources). Or, in more general terms, that economic growth driven by trade may speed up the process of environmental degradation unless environmental safeguards are put in place.

The basic assumption of these arguments is that environmental standards are weaker in developing countries, encouraging the migration of pollution-intensive industries (for a review of these arguments, see Leonard, 1988, and Weil *et al*., 1990). Empirical evidence shows that polluting industries have in fact expanded faster in developing countries than the average rate for all industries (Lucas *et al*., 1992; Low and Yeats, 1992). However, the evidence is not clear about the existence of a migration process of dirtier industries from developed countries.

Using trade and investment figures for US-based industries, Leonard (1988) concludes that, taken in the aggregate, the years immediately following the emergence of stringent environmental regulations in the US did not witness widespread reallocation of pollution-intensive industries to countries with drastically lower regulatory requirements. Pollution abatement and control expenditures seem not to have significant effects on competitiveness in most industries, since they are small in comparison with total costs.

Other reasons can be listed (Low, 1992), such as the fear of liability in the event of an accident; the reputation damages in the originating countries if it happens; the costs of 'unbundling' technology; potential claims of environmentally-concerned consumers in export markets; expectations of more stringent local environmental standards in the future; and the relatively high costs of retrofitting ageing capital equipment instead of starting up with 'top of the line' equipment. It has been observed empirically that open developing economies became less pollution intensive than closed economies in the 1970s and 1980s (Lucas *et al*., 1992; Birdsall and Wheeler, 1992).

This lack of a definitive answer to these opposing arguments is consistent with the results of recent surveys of theoretical models dealing with the issue (Ulph 1998):

> "The literature has been timely in that the issue (the link between environmental policy and international trade) has been one of considerable public debate, and the literature has been well placed to address some of the issues raised by that debate, since the literature has focused on imperfect competition and the potential scope for governments to manipulate environmental policy for strategic reasons. I have shown that this recent analysis is capable of providing starkly different predictions of environmental policy under liberalised trade regimes from those derived from the traditional literature, but there is a severe problem of non-robustness of results. This is especially problematic when it comes to trying to draw policy conclusions from this new literature, although the analysis does not support some of the policy prescription discussed in popular debates". (Ulph 1998, p.237-238)

There is a need for further theoretical and empirical research. The following sections are an attempt to contribute to debates in both areas.

3. Industry and the environment in Brazil

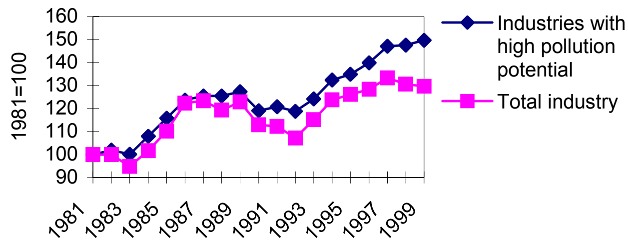
3.1 Environmental regulation in Brazilian industry

Since the 1990s, the Brazilian economy has experienced a series of reforms directly inspired by the “Washington consensus” agenda. They include privatisation, reduced participation of the government in the productive sector, and the liberalization of capital and trade flows. Nevertheless, economic growth has not ensued and the economy has demonstrated a persistent trend toward stagnation.

During the same period, there is evidence that the pollution problem has increased in Brazil. The Brazilian Statistical Office (IBGE) has created an index of industrial growth according to a classification of potential pollution, following the methodology proposed by Carvalho and Ferreira (1992). The index combines output data from IBGE's monthly industrial survey, classified according to the air and water pollution potential of each product, as 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.

Figure 1 suggests that the industries with high pollution potential grew at higher rates than the average of the Brazilian industry, and that the dynamics of industrial growth in the Brazilian industry since the 1980s has been positively correlated with the level of potential pollution.

Figure 1. Evolution of the Brazilian industry according to its potential pollution (1981=100)



Source: IBGE/DPE/Industry Department

One possible interpretation of this result is that the performance of the Brazilian industrial sectors was dependent on their potential of pollution emissions. This could be the consequence of implicit incentives for "dirty" sectors because of a new international division of labour, as suggested by the "pollution haven" literature. The following sections discuss this possibility through a series of empirical exercises.

3.2 Using the input-output model to estimate industrial emissions

In order to capture all industrial pollution generated in the whole industrial processing of a manufactured good we need to account for all emission flows from the input production up to the assembling phase. Such approach requires the application of an input-output model relating changes on demand vectors to potential industrial pollution levels.

The objective of the input-output model is to describe the interdependence of the economy, given the current levels of production and consumption (see Leontief, 1966). 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 is based on the identity between aggregate supply and demand. The intermediate consumption "x_{ij}" represents the amount of output from sector "i" that is demanded as input by sector "j". Private consumption "C_i", investment "I_i", public administration consumption "G_i", and exports "E_i" represent the amount of domestic production that is destined to final demand, and M_i represent the supply of imported goods in the same period.

$$x_i = \sum_{i=1}^{n} x_{ij} + C_i + I + G_i + E_i - M_i \qquad (1)$$

The basic assumption of the model is to consider the intermediate consumption as a fixed proportion of the total output of each product:

$$x_i = \sum_{j=1}^{n} a_{ij} \cdot x_j + d_i \qquad (2)$$

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 can be represented by:

$$x = Ax + d \qquad (3)$$

Where "x" is the (n x 1) vector with the total product of each sector, "d" is the (n x 1) vector with sector final demand, and "A" is the (n x n) matrix with the technical coefficients of production.

In its most basic version, the solution of the model uses the $(I - A)^{-1}$ matrix containing the (n x n) input-output coefficients to estimate the total output in each sector that is required for the achievement of a given final demand vector:

$$x = (I - A)^{-1} d \qquad (4)$$

Extended input-output tables became a useful tool to estimate emissions and other discharges of residuals in order to assess environmental problems at the macroeconomic level (see Leontief, 1970; Førsund, 1985). 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. Young (1998; 2001) originally developed the model below in a series of studies aiming at the estimation of the emission impacts of the export complex in the Brazilian industry.

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):

$$ef_{hi} = \frac{em_{hi}}{x_i} \qquad (6)$$

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:

$$z_{hf} = diag(ef_h) \cdot x_f = diag(ef_h) \cdot (I - A)^{-1} d_f \qquad (7)$$

Where "z_{hf}" is the (n x 1) vector containing the total emission of pollutant "h" per sector associated to the f-category of final demand, and diag (ef_h) is the (n x n) matrix containing in its principal diagonal the emission factors of pollutant h for each sector, and zeroes elsewhere (Pedersen, 1993). In other words, "z_{hf}" is an estimate of how much emission of pollutant "h" is generated by the production of one unit of output in sector "i", given a "d_f" scenario in the final demand.

Note that it is possible to disaggregate the changes in the emission pattern of the industry in three different effects:

a) Scale effect: refers to changes in emissions caused by the changes in the overall output level caused by the expansion (or retraction) of economic activities. If only the scale effect is considered, the level of emissions would change in the same proportion as the GDP.

b) Composition effect: refers to changes in emissions caused by the industrial restructuring that takes place within the economy. The composition effect considers the effects on total emissions because some sectors have increased their share in the economy's total output, while others have it reduced – if these sectors have different emission profiles, total emissions would have changed even if GDP has remained at the same level.

c) Technology (or technique) effect: refers to changes in emissions caused by the alteration of the capital stock, including the introduction of innovations and technical progress. This means that no constant relationship can be established between output and the level of emission in the long term.

The input-output model allows the identification of the scale and composition effects, but the technology effect cannot be captured because of the use of fix emission coefficients. Therefore, the simulation exercises carried out in the following section do not consider changes in the environmental profile of the Brazilian industry, in spite of the signals of increasing investment in pollution control.

Another important gap in the analysis is the impossibility of estimating accidental emissions. This is the issue that catches most attention from environmentalists and the public in general, but there is no database that manages this kind of information for all economic sectors.

3.3 Estimating industrial pollution in Brazil

There are no systematic measurements of pollutant emissions in Brazil. Therefore, proxies have to be used in order to estimate them. Following the methodological approach used in previous studies (Young 1998, 2001), estimation exercises were carried out combining the input-output tables of the Brazilian Geographical and Statistical Institute (IBGE) with different sets of emission coefficients, described below. The time period considered was limited by the range of the available IBGE input-output tables: 1985, 1990, 1991, 1992, 1993, 1994, 1995 and 1996.

3.3.1 The IPEA emission coefficients (local pollutants)

The first set of emission coefficients (for local pollutants) was extracted 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.[4] 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 Program 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 respective state environmental agency by emission parameters obtained from the technical literature

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

(mostly taken from the World Health Organisation). These potential pollution emissions were considered as a measure of the level of pollutant emitted by the industrial establishment without any treatment.

The second stage was to estimate the level of remaining emissions (potential emissions minus abatement capacity), considered a better proxy for the effective level of industrial emissions. The pollution treatment capacity of every industrial unit was calculated according to the potential for emission treatment at the source points (i.e. every industrial establishment registered in the database). The indicators of (remaining) emissions were then divided by the value added of the respective industrial sectors, at the state level, in order to produce the emission intensity coefficients (for more details, see Mendes 1994).[5]

Table 1 presents the estimated emission coefficients for each category of final demand, measured in terms of kg of pollutant per US$ Million of output.

[5]One adaptation was required because the above emission coefficients were based on the value added (VA) for each industrial sector. However, equation (6) refers to the total value of production (VP), including intermediate consumption. 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 that could be applied to the direct and indirect effects of each category of final demand.

Table 1. Pollution intensity per unit of output (kg/US$ Millions)

Parameter/year	Investment*	Exports	Public Consumption	Private Consumption	Total
BOD					
1985	569	1420	361	1298	1043
1990	436	1292	277	1243	936
1995	453	1370	288	1116	861
Metals (water)					
1985	31	44	3	14	21
1990	24	50	3	13	17
1995	24	47	2	10	15
Particulates (air)					
1985	9364	7760	1296	4118	5553
1990	9390	8497	1041	3938	5035
1995	8232	8549	1034	3398	4441
SO_2					
1985	4146	6957	1134	4268	4278
1990	3520	6441	884	3983	3652
1995	3356	6442	855	3528	3298
NO_X					
1985	1878	3243	860	2011	2029
1990	1613	2969	646	1918	1763
1995	1574	3029	666	1672	1603
HC					
1985	674	1105	188	585	636
1990	575	974	148	554	537
1995	566	880	138	430	448
CO					
1985	40265	51294	4525	14781	24792
1990	32104	58715	3519	13318	20030
1995	31445	55460	3113	10899	17855

* Investment includes changes in stocks

For all pollutants analysed, 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 all but one parameter (particulates, in which exports are the second highest). In other words, exports are more pollution-intensive than the average of the economy for almost every pollutant considered.

In sector terms, it is clear that a few sectors account for most industrial water and air pollution. These 'dirty' industries are usually related directly or indirectly to export oriented activities, such as metallurgy (input for the automobile 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.

If the (fixed) emission coefficients estimated by IPEA with data for the Brazilian industry (for the 1988/91 period) are applied to a time series up to 1995, there is a clear trend of reducing the average intensity of emissions per unit of output for all parameters considered. This indicates that the composition of the Brazilian industrial output has changed towards less (potentially) pollutant activities. However, the emission intensity in the export complex for metals, particulates and CO would have increased, showing an increase in the dependence of Brazilian industrial exports in (potentially) dirty activities.

Note that it is important to bear in mind the many limitations involved in this approach. Among them, three are particularly important. First, the emission estimates were not obtained directly from observations of the quality of water and air at the emission points but indirectly, by the specifications of the industrial plants surveyed. However, the environmental impact of a specific pollutant is affected by many other variables that were not considered in the exercise.[6] Second, a linear relationship is assumed between value added and the level of emissions - it is possible that this relationship is far more complex. Third, only the establishments that were registered with the environmental agencies could be considered. It is possible that the total amounts of emission were 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 emission.

3.3.2 IPPS emission coefficients (local pollutants)

Production and emissions data from 200,000 factories in the United States (1987) were merged to obtain estimates of sector pollution intensity (pollution per unit of activity), and used by the World Bank as the basis for the Industrial Pollution Projection System (IPPS). Although the estimates based on the IPPS would not be actual emissions, they can be useful as a guideline in order to rank industrial sectors in terms of its potential emissions[7].

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[6] The primary data on water emissions were scanned in the work by Mendes (1994); however the data on air emissions were not. This represents another potential difficulty for the exercise, even though the most significant problem identified in the primary data concerned the leather and footwear sector, which is not a main source of air emissions.

[7] For more detail on the construction of the IPPS database see Hettige *et.al.* (1994).

The IPPS index expresses the pollutant output intensity for six types of air pollutants (SO_2, NO_2, CO, VOC, PM10, TP), three types of water pollution (BOD, TSS and metal) and metals disposed in landfills.[8] Pollution intensity is expressed as pollutant output divided by total manufacturing. The total manufacturing activity can me measured by many variables, but the main choice is between the value and the output quantity. Only industrial activities are covered.

The IPPS provides emission coefficients based on the value of production (*shipment value*), value added or employment. Since the input-output coefficients usually refer to the first of these categories, the coefficients used in this exercise refer to emissions divided by the value of production. Additionally, it is very important to mention that the EPA data used to calculate the IPPS coefficients only cover facilities releasing pollutants over a threshold level of emissions. Consequently, pollution intensities based on these data may be biased. In this study, it was decided that the *lower bound* coefficients were more appropriate to estimate the Brazilian industry environmental performance. These coefficients assume the hypothesis that non-reporting facilities had no emissions (i.e., they were assigned with zero emissions). Hence, there is an underestimation bias in the calculation of emissions using these coefficients.[9]

The use of IPPS coefficients in the estimate of Brazilian industrial emissions also assumes that there were no significant technical differences between the production sectors in both countries (at least in terms of average emission per unit of output). Therefore, since the effective degree of emission treatment in Brazil is unknown, it is very likely that errors result from the application of the IPPS coefficients. Moreover, since the denominator is expressed in monetary terms (value of production), an additional assumption is that the relative price structures in both countries are the same, which is very unlikely to happen in real terms. Finally, there is the problem of translating the classification of IPPS coefficients to the IBGE input-output classification. The aggregation level of IPPS is the International Standard Industrial Classification (ISIC) level 4, more detailed than the classification level 80 adopted in the input-output tables of IBGE. This also includes the problem of non-equivalence in the translation of classifications, such as the lack of IPPS emission

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[8]The IPPS also provides aggregate estimates of toxicity; however, since the interpretation of these aggregates is not an easy task, they were not considered in this analysis.
[9]On the other hand, the other option (*interquartile* coefficients), which consider the emissions of industries in the second and third quartiles, presents even more complicated problems, including the lack of sufficient data for some sectors, and that it is not possible to see if the coefficient has an underestimation or an overestimation bias.

coefficients for the coffee industry (which emission coefficients were considered as zero) and alcohol processing (aggregated to sugar processing in the IPPS, but considered by IBGE together with chemical elements).

In summary, the results obtained through these coefficients (Tables 2 to 10), must be examined with extreme caution because of the methodological problems described above and, as already warned, they can only be considered as *potential* indicators of actual emissions (which are, in fact, unknown).

Table 2. Emission intensities: BOD, kg/US$ millions (1987), IPPS coefficients

Year	Consumption	Investment	Exports	Total
1985	310	130	195	252
1990	315	126	245	265
1991	316	130	242	268
1992	316	118	235	265
1993	299	121	227	253
1994	287	117	244	246
1995	283	113	285	248
1996	285	125	276	253

Table 3. Emission intensities: Total Suspended Solids, kg/US$ millions, IPPS coefficients

Year	Consumption	Investment	Exports	Total
1985	3713	9587	11726	6368
1990	3771	8405	14368	6091
1991	3502	8095	14973	6094
1992	3354	8407	13893	6216
1993	3314	8599	13786	6158
1994	3520	8969	13187	6131
1995	3488	8428	12976	5781
1996	3507	8765	13202	5792

Table 4. Emission intensities: SO2, kg/US$ millions, IPPS coefficients

Year	Consumption	Investment	Exports	Total
1985	1904	2871	3492	2389
1990	1977	2724	3817	2368
1991	1944	2762	3654	2356
1992	1915	2712	3498	2352
1993	1876	2758	3459	2322
1994	1884	2704	3538	2308
1995	1850	2558	3704	2244
1996	1853	2735	3678	2263

Table 5. Emission intensities: NO_2, kg/US$ millions, IPPS coefficients

Year	Consumption	Investment	Exports	Total
1985	1142	1339	1726	1287
1990	1210	1327	1663	1292
1991	1195	1354	1576	1283
1992	1197	1352	1536	1288
1993	1163	1343	1515	1259
1994	1159	1300	1543	1247
1995	1131	1217	1616	1213
1996	1127	1304	1562	1218

Table 6. Emission intensities: CO, kg/US$ millions, IPPS coefficients

Year	Consumption	Investment	Exports	Total
1985	1743	2447	3152	2141
1990	1793	2280	3520	2114
1991	1757	2267	3520	2117
1992	1717	2285	3339	2118
1993	1685	2332	3329	2097
1994	1725	2344	3339	2102
1995	1671	2218	3388	2013
1996	1683	2347	3410	2037

Table 7. Emission intensities: VOC, kg/US$ millions, IPPS coefficients

Year	Consumption	Investment	Exports	Total
1985	835	788	1176	885
1990	875	788	1076	881
1991	868	799	996	873
1992	864	787	991	873
1993	854	792	981	865
1994	852	781	1008	862
1995	828	742	1032	837
1996	825	781	1002	840

Table 8. Emission intensities: Fine particulates, kg/US$ millions, IPPS coefficients

Year	Consumption	Investment	Exports	Total
1985	264	753	546	417
1990	268	723	610	408
1991	264	756	584	408
1992	266	763	568	414
1993	256	755	578	406
1994	257	707	565	396
1995	264	662	585	390
1996	261	717	584	391

Table 9. Emission intensities: Total particulates, kg/US$ millions, IPPS coefficients

Year	Consumption	Investment	Exports	Total
1985	514	880	844	649
1990	519	849	904	638
1991	518	885	836	637
1992	523	882	832	647
1993	504	877	842	634
1994	503	825	855	623
1995	506	775	928	618
1996	501	839	907	619

Table 10. Emission intensities: Metals - land, kg/US$ millions, IPPS coefficients

Year	Consumption	Investment	Exports	Total
1985	138	331	363	219
1990	140	292	465	213
1991	132	289	470	212
1992	124	284	438	211
1993	124	298	434	211
1994	129	305	431	212
1995	128	291	439	203
1996	129	306	453	206

Despite the difference in the source of the coefficients from the previous exercise, the conclusions tend to be very similar: the emission intensity of the export complex is always higher than the average emission intensity of the economy and, in almost all cases, the highest emission intensity was exactly the one of the export complex.

The average emission intensity of the economy for all parameters has declined between 1985 and 1996 (with the exception of BOD, which has remained almost the same); nevertheless, the emission intensities in the export complex have increased for all but two parameters (NO_2 and VOC).

The emission intensities estimated according to the IPPS coefficients are considerably lower than the values obtained using the IPEA coefficients; this is a strong indication that the environmental profile of the Brazilian industry in the late 1980s was considerably worse than the US one.

These results are very consistent showing a trend that exports are dependent on production chains that are potentially dirtier (according to the IPPS) than the average of the economy. Despite the methodological problems discussed previously, this is a strong indication of a composition effect in the direction of specialisation in (potentially) contaminant industries.

3.3.3 IPEA-IE/UFRJ Emission coefficients inventory (local pollutants)

The third database used to estimate the emission of local pollutants by the Brazilian industry was built specifically for this study using data from CETESB (the environmental agency for the State of São Paulo). The calculation of industrial emissions generated in São Paulo was based on the information declared by local production units about their potential emissions and their capacity to abate them (obtaining, by residual, the level of remaining emissions) according to the CETESB inventory. Note that, again, these data do not refer to actual emissions, but to information given by the industries to the environmental agency (in that case, up to the end of 1996); therefore they also refer to "theoretical" (rather than observed) emissions.

These figures were then divided by the value of production (or value added, or employment) for every industrial sector in the State of São Paulo, in order to generate the emission coefficients. Ideally, the production data would have been obtained directly from the same local units surveyed by CETESB. However, since this comparison is impossible, the value of production of the São Paulo industry, by sector, estimated by the Annual Industrial Survey (PIA/IBGE) for the year 1996 was used. Once the coefficients were estimated, they were applied to the industrial value of production for the country as a whole (assuming that the environmental performance of industries in São Paulo reflect the average behaviour of Brazilian industry).

The emission coefficients obtained using these procedures were water pollutants: organic and inorganic; air pollutants: sulphur dioxide (SO_2) and particulates (total). Table 11 presents the results using the emission coefficients estimated according to the CETESB inventory.

Table 11. Emission intensities, kg/US$ millions, IPEA-IE/UFRJ coefficients

Pollutant/year	Consumption	Investment	Exports	Total
Organic				
1985	956	203	534	723
1990	937	203	590	736
1991	973	210	591	766
1992	972	199	623	764
1993	932	196	625	740
1994	925	184	647	732
1995	923	177	779	747
1996	903	190	744	744
Inorganic				
1985	7.7	7.6	8.8	7.9
1990	7.4	7.2	10.4	7.7
1991	6.9	7.2	10.5	7.5
1992	6.5	7.1	10.9	7.4
1993	6.8	7.4	11.4	7.7
1994	7.0	7.5	10.5	7.6
1995	6.8	7.3	10.5	7.4
1996	6.6	7.2	11.5	7.4
Particulates				
1985	2542	2839	2186	2542
1990	2378	2811	2384	2472
1991	2514	3019	2427	2601
1992	2617	3018	2470	2666
1993	2351	2974	2550	2503
1994	2445	2723	2843	2563
1995	2350	2549	3983	2608
1996	2388	2794	3667	2634
SO_2				
1985	928	1150	1026	992
1990	946	1158	943	991
1991	965	1232	894	1008
1992	977	1231	889	1009
1993	952	1220	890	991
1994	949	1129	919	981
1995	934	1058	945	962
1996	934	1151	939	976

These results have important differences from the previous exercises. Firstly, it is important to note that the emission coefficients are considerably smaller than the ones based on the IPEA data, but yet higher than those from IPPS. Considering the estimates for 1995, the average intensity for organic matter (equivalent to BOD) based on the IPEA-IE/UFRJ coefficients is 747 kg/US$ Million, in contrast to 861 kg/US$ Million estimated with the IPEA coefficients, and 248 kg/US$ Million using the IPPS. The intensity for particulates obtained from the IPEA-IE/UFRJ coefficients is 2608 kg/US$ Million, while the same estimate using IPEA's coefficients is 4441 kg/US$ Million and 618 kg/US$ Million using the IPPS. The only exception is SO_2: the estimate of emission intensity based on the IPEA-IE/UFRJ coefficients (962 kg/US$ Million) is smaller than the other two estimates (3298 kg/US$ Million using IPEA, and 2244 kg/US$ Million using IPPS). This may be an evidence of the improvement in the environmental performance of the Brazilian industry during the 1990s, even though it still emits more than the US industry used to emit a decade before (with the exception of SO_2).

Another important point is that the difference between the emission intensities of the export complex and the average of the economy is not so accentuated as in the previous cases. Indeed, the export complex intensity gets below the average intensity in some cases, particularly for SO_2. Nevertheless, in general terms, the conclusions are similar to the previous ones: the export complex tends to be more intensive in emissions than the rest of the economy (even though the difference to the other sectors is less accentuated).

3.3.4 Carbon dioxide emissions from fossil fuels consumption (global pollutant)

A study by COPPE/UFRJ (1998) estimated carbon dioxide (CO_2) emissions from fossil fuel consumption in Brazil in the period 1990/94. These data were obtained using the methodological procedures of the Intergovernmental Panel on Climate Change (IPCC) since they were used in the Brazilian official inventory of greenhouse gas emissions. Table 12 summarises the main results.

Table 12. CO2 emissions from fossil fuels consumption, Brazil (1990/94)

Sector	1990		1991		1992		1993		1994	
	1000t CO_2	%	1000t CO_2	%	1000t CO_2	%	1000t CO_2	%	1000t 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)

Using the same approach of the other exercises, based on equation (7), Table 21 presents the intensity coefficients (CO_2 per unit of output) in each production chain:

Table 13. Emission intensity per unit of output (kg CO2/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), it remained almost as the double of the average intensity of the economy. This is another strong evidence that the Brazilian economy has exported goods and services based on “dirty” activities.

In sector 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.

We conclude that despite of all limitations (pollution estimates were not directly observed; the environmental impact of a specific pollutant is affected by many other variables which were not considered in the exercise; linear relationships between output and emissions may not be realistic; etc.) the results from these exercises are very consistent in showing the relatively high contribution of export oriented activities to air and water pollution problems in Brazil. The convergence 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 another strong element confirming the relative specialisation in dirty industrial exports. Therefore, any expansion of export activities based on the existing set of parameters will lead to problems of increasing the level of industrial emissions more than a similar rise in domestic-oriented activities.

Nevertheless, it is crucial to note that only the composition effect was considered in these exercises. Most of the argument that more openness brings benefits to the environment is based on another aspect, the technological effect. This issue is discussed further ahead, in the following section.

3.4 Imports and emission "savings"

3.4.1 Estimating emission savings

An integrated analysis of the environmental impacts of international trade has to consider that liberalisation may have an important impact on pollution because import goods reduce domestic levels of emission. Since they are produced abroad, imports "deviate" the associated emissions to the country where the good was made – the idea is that, if no trade relations were kept, they would have been produced domestically, increasing the level of emissions.

In this section, we examine the emission "savings" caused by the fast growth of industrial imports in Brazil after the trade liberalisation policies. These emission savings were estimated through the hypothetical increase in emissions if these import goods were made in Brazil. In methodological terms, this can be done using the same input-output and emission coefficient tables presented in the exercises in the previous section, but with a change: instead of using the supply and demand tables of domestic products, in this exercise it was used the table of the supply and demand of import goods. The emission coefficients were obtained from the already mentioned Industrial Pollution Projection System (IPPS) of the World Bank.

The flagship of the liberalisation process was the automobile imports, which increased 1380% in the 1990-96 period. Other industrial sectors with very high rates of import growth where plastics (307%), textiles (286%), wood and furniture (248%), electronics (246%), other industries (220%), other metallurgic goods (200%), car components (200%), electrical equipment (199%) and vegetable oils (193%). The average increase in industrial imports were 148%, and the sectors with the lowest rates of import growth were slaughtering (-41%), sugar production (73%), footwear (78%) and chemical elements (88%).

Table 14 shows the aggregate emission savings for each pollutant in the 1990-1996 period. The average change in the associated level of (potential) emissions was 46%. At a first sight, this suggests a relative stability in the composition of imports in terms of emissions. However, one can observe that there were considerable differences between pollutants. In the case of metal emissions for water and BOD, for example, the growth in domestic emission savings was considerably below the average, showing that the composition of imports changed towards goods with low intensity in this water pollutant. On the other hand, the presence of import goods intensive in air pollutants (VOC, metals, SO_2 and NO_2) has increased in the same period, indicating that the emission savings effect have grown for these parameters.

Table 14. Emission savings (tons), IPPS coefficients, 1990-96

Pollutant	1990	1996	Change
BOD	6,183.86	14,262.22	131%
Total Suspended Solids	175,387.86	429,782.33	145%
SO_2	65,818.26	167,426.61	154%
NO_2	32,209.98	82,996.04	158%
CO	60,391.33	150,209.10	149%
VOC	23,963.26	63,944.79	167%
Fine Particulates	7,666.07	19,514.42	155%
Particulates (total)	12,870.87	33,092.61	157%
Metals – air	13,569.27	35,060.37	158%
Metals – land	28,751.79	66,923.65	133%
Metals – water	2,520.36	5,344.16	112%
Imports	20,602.72	51,017.03	148%

Combining the emission savings in physical units with their output value, it is possible to estimate the avoided emission intensity per unit of imports (shown in Table 15). Following the same pattern described previously, there is an asymmetry between water and air pollutants: while there was a decrease in the emission intensity of water and land pollutants per unit of import, the air pollutants presented an opposite trend of increasing emission intensities.

Table 15. Emission intensity per unit of imports (g/US$), IPPS coefficients, 1990-96

Pollutant	1990	1996	Change
BOD	0.30	0.28	-6,86
Total Suspended Solids	8.51	8.42	-1.04
SO_2	3.19	3.28	2.73
NO_2	1.56	1.63	4.06
CO	2.93	2.94	0.45
VOC	1.16	1.25	7.76
Fine Particulates	0.37	0.38	2.80
Particulates (total)	0.62	0.,65	3.83
Metals – air	0.66	0.69	4.34
Metals – land	1.40	1.31	-6. 00
Metals – water	0.12	0.10	-14. 37

3.4.2 Comparing export and import emission intensities

The exercise that is most important for policy analysis is the comparison between the import and export emission intensity coefficients. This is shown in Table 16, based on the results of this and the previous section. It is clear that the potential emission per unit of exports is always superior to its equivalent for imports for every single parameter considered. The reason for this is that the composition of the production chain associated with Brazilian industrial exports is more concentrated in potentially dirty activities than the production chain that would be required if the imports were produced domestically. In other words, Brazil is a net “exporter” of sustainability, in the sense that its insertion in the international market is through the production of potentially pollutant industrial goods, while it consumes products that are less harmful to the environment.

Table 16. Difference between export and import emission intensities (g/US$)

Pollutant	1990	1991	1992	1993	1994	1995	1996
BOD	0.03	0.03	-0.01	0.08	0.06	0.14	0.08
TSS	11.73	11.83	9.37	10.29	8.72	7.31	8.23
SO_2	2.10	1.83	1.24	1.64	1.56	1.31	1.50
NO_2	0.65	0.58	0.33	0.51	0.55	0.42	0.47
CO	1.93	1.84	1.29	1.63	1.41	1.16	1.33
VOC	0.28	0.18	0.04	0.14	0.18	0.04	0.10
Particulates	0.50	0.48	0.37	0.47	0.42	0.42	0.42
Fine particulates	0.67	0.61	0.45	0.63	0.60	0.63	0.63

Again, it is important to bear in mind that these results reflect the composition structure of exports and imports based on the hypothesis of fix emission coefficients. One argument in favour of the trade liberalisation process is the improvement of the environmental performance of industries because capital goods can be imported more easily, thus introducing better emission standards (since they are designed for the more restrictive markets of developed countries). However, this cannot be empirically verified in exercises using fix emission coefficients, such as the ones carried out in this report. The improvement in data availability for the effective environmental performance of the industry, instead of proxies based upon fix emission coefficients, is a need for the better understanding of the connections between economic and environmental variables.

We conclude that a positive environmental effect of the fast expansion of imports in the 1990s in Brazil was the avoidance of emissions associated with these goods. However, that this counterbalancing effect was much attenuated by the composition of the import goods basket, compared to the exports: the growth in industrial imports was concentrated in relatively clean activities, while the structure of industrial exports remained associated with more emission intensive sectors. Therefore, the overall reduction in the (potential) emission of pollutants in the Brazilian industry caused by imports growth was smaller than it could have been if these imports were concentrated in "dirtier" activities.

3.5 Brazilian competitiveness and the control of water emissions

The previous sections showed that the presence of emission-intensive products in the composition of Brazilian industrial exports is significant. This conclusion brings two kinds of problems: the welfare losses caused by pollution but, because of the lack of an environmental accounting system, are not accounted for if external markets become more rigorous in terms of environmental standards, and the treatment costs being high, the competitive advantage of lower production costs for being "dirty" turn out to be a disadvantage.

The first issue has already been analysed by specialists, alerting that *laissez faire* environmental policies may end up with social costs higher than the benefits. This chapter discusses the second issue, which has received less attention from the literature. In other words, how much it would cost to clean up production, and what would be the trade losses if export prices go up because of the former?

3.5.1 The theoretical model

The analysis in this chapter follows the approach by Pasurka (1984) to estimate the direct and indirect price effects caused by higher environmental protection costs. The idea is that pollution control costs raise prices of various products and their respective inputs at the domestic level, but not the prices in international markets (given, assuming that Brazilian firms are price-takers). The price increases for inputs must be transmitted to the outputs, generating a chain of inflation in the economy. In terms of the input-output approach, the final price increase can be represented by:

$$\Delta P = v\,(I - A)^{-1} - v^{*}\,(I - A^{*})^{-1} \quad (9)$$

Where ΔP is a vector of the absolute as well as proportionate price changes, V is the vector representing the sum of the costs of direct labour and capital services used in the production and pollution control activities, V^* is the v matrix only respective to production activities, A^* is the matrix of direct intermediate input coefficients only respective to production activities.

Assuming that the exchange rate is not affected, the international price of the good is increased and its competitiveness reduced. The dimension of the impact will be dependent on the demand price-elasticity of Brazilian export goods.

Some additional hypothesis was necessary for this approach. The intermediate consumption for the pollution abatement activities could not be included because of the lack of data (to fix this, the whole input-output table would have to be modified). Another assumption is that the costs of treating pollution do not affect the technical coefficients of the matrix. Also, it is assumed that the production factors necessary for the pollution control activities are not employed for other activities, otherwise it would have generated a reallocation of production factors incompatible with the existing composition of the aggregate value. Finally, since it refers to a short term, partial equilibrium analysis, the impacts of pollution control over investment (and, consequently, economic growth) could not be considered. This is equivalent to consider that all costs associated with environmental protection are fully incorporated in prices (mark up hypothesis), characterising these markets as of imperfect competition at the domestic level (despite the export goods are considered as price takers).

3.5.2 Control costs for water emissions from Brazilian industry

For the simulation exercise, emission control costs were obtained from simulations based on original parameters developed by Mendes (1994). Only the costs for controlling water emissions from industrial sources were considered, corresponding to organic matter (BOD) and toxic metals, including investment costs.[10] The estimates were based on the emission volume calculated according to the IPEA coefficients, and the cost parameters developed by Mendes (1994), which were partially derived from a World Bank study based on Brazilian data that

[10]A similar exercise was carried out using emission control costs available in the IPPS; nevertheless, in this case, they refer to the average current costs of the US industry in emission control for the year 1994. Hence, the results were considerably smaller than those obtained using the Mendes (1994) coefficients. In order to avoid further confusions (and because the underestimation was much more significant than in the case of emission estimates and these values more precarious), these results were left out of this report.

estimated the costs for pollution control, and economic data for the Brazilian industry from IBGE.

The costs of emission control were calculated for three different scenarios: removal of 50%, 75% or 100% of the pollutants. Each one of these scenarios can be thought as different degrees of requirement in the legislation referring to pollution control. As stated previously, the emission control costs were disseminated through the production chain according to the relative weight of each input to the overall production costs, according to the methodology proposed by Pasurka (1984).

Table 17 presents the estimation of cost increases per sector. In general terms, the increase in costs is not very large: 93% of the economic activities presented cost increases in the range between 0% to 3% of the value added. Even when the total removal is imposed (100% scenario), most sectors would have an increase of costs lower than 1.0% of the value added.[11]

As expected, the sectors with higher (direct) control costs are the ones that present higher increases in total costs. The more problematic industries are non-ferrous metallurgic, other metallurgic, and footwear. Only these three sectors would have costs superior to 3% in the three scenarios, indicating that more dramatic impacts of losing competitiveness associated with tougher environmental measures would be concentrated in a few number of industries.

The sectors with cost increases between 1% and 3% represent 26% of the total number of sectors in the most exigent scenario (100% removal). However, this proportion falls to less than 10% with the smallest level of exigency (50% removal), and includes machinery and equipment, electric material, vehicle parts and other vehicles, and wood and furniture.

It is interesting to note that these low values are compatible with a questionnaire survey carried recently (BNDES/CNI/SEBRAE 1998), showing that most of the Brazilian industrial companies (65%) declared operational environmental costs at the lowest range indicated by the survey (less than 5% of operational revenues). In any case, it is also important to highlight that the BNDES/CNI/SEBRAE survey asked about costs already faced by the industry, while the Mendes (1994) coefficients refer to the expenditures that are necessary to remove emissions, but have not yet been implemented.

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[11]The result that cost increases are not very large is similar to the estimates of Pasurka (1984) and other studies for the US (such as Repetto *et al.* 1994).

Table 17. Proportion of direct and indirect costs for controlling industrial water emissions, as a proportion of the sector value added

Activities	50%	75%	100%	50%	75%	100%
Agriculture	0. 00%	0.00%	0.00%	0.13%	0.17%	0.31%
Mineral extraction	0.00%	0.00%	0.00%	0.31%	0.36%	0.55%
Oil and natural gas	0.00%	0.00%	0.00%	0.27%	0.31%	0.47%
Non-metallic minerals	0. 00%	0.00%	0.00%	0.28%	0.33%	0.51%
Iron and steel	0.00%	0.00%	0.00%	0.52%	0.61%	0.92%
Non-ferrous metallurgic	5.30%	6.18%	8.99%	7.71%	9.00%	13.15%
Other metallurgic	5.30%	6.18%	8.,99%	6.55%	7.64%	11.15%
Machinery and equipment	0.00%	0.00%	0.00%	1.10%	1.28%	1.89%
Electric material	0.00%	0.00%	0.00%	1.54%	1.80%	2.66%
Electronic material	0.00%	0.00%	0.00%	0.47%	0.55%	0.81%
Motor vehicles	0.00%	0.00%	0.00%	0.99%	1.15%	1.72%
Vehicle parts and other vehicles	0.00%	0.00%	0.00%	1.41%	1.64%	2.42%
Wood and furniture	1.00%	1. 06%	1.37%	1.56%	1.70%	2.34%
Pulp, paper and paperboard	0.16%	0.18%	0.55%	0.46%	0.54%	1.22%
Rubber industry	0.00%	0.,00%	0.00%	0.28%	0.33%	0.53%
Chemical industry	0.39%	0.57%	1.19%	0.62%	0.84%	1.63%
Petroleum refineries	0.00%	0.,00%	0.00%	0.17%	0.20%	0.32%
Other chemical products	0.39%	0.57%	1.19%	0.72%	0.98%	1.91%
Pharmacy and veterinary products	0.03%	0.03%	0.06%	0.28%	0.34%	0.59%
Plastic products	0.00%	0.00%	0.00%	0.20%	0.24%	0.39%
Textiles	0.48%	0.53%	0.74%	0.92%	1.03%	1.48%
Wearing apparel	0.48%	0.53%	0.74%	0.98%	1.09%	1.64%
Footwear	5.01%	5.96%	16.01%	6.42%	7.64%	20.24%
Coffee industry	0.13%	0.14%	0.29%	0.28%	0.33%	0.63%
Other vegetable products	0.13%	0.14%	0.29%	0.35%	0.40%	0.71%
Meat industry	0.13%	0.14%	0.29%	0.31%	0.36%	0.68%
Dairy products	0.13%	0.14%	0.29%	0.44%	0.50%	0.89%
Sugar factories and refineries	0.13%	0.14%	0.29%	0.43%	0.50%	0.87%
Vegetable oils	0.13%	0.14%	0.29%	0.48%	0.55%	0.95%
Other food products	0.13%	0.14%	0.29%	0.46%	0.53%	0.95%
Other industries	0.00%	0.00%	0.00%	0.53%	0.62%	0.95%
Public utilities	0.00%	0.00%	0.00%	0.14%	0.16%	0.25%
Civil construction	0.00%	0.00%	0.00%	0.75%	0.87%	1.28%
Commerce	0.00%	0.00%	0.00%	0.07%	0.09%	0.15%
Transportation	0.00%	0.00%	0.00%	0.17%	0.20%	0.31%
Communications	0.00%	0.00%	0.00%	0.13%	0.15%	0.24%
Financial institutions	0.00%	0.00%	0.00%	0.03%	0.03%	0.06%
Services to households	0.00%	0.00%	0.00%	0.25%	0.29%	0.46%
Business services	0.00%	0.00%	0.00%	0.07%	0.08%	0.16%
Renting	0.00%	0.00%	0.00%	0.11%	0.12%	0.18%
Public administration	0.00%	0.00%	0.00%	0.07%	0.09%	0.15%
Non-mercantile private sectors	0.00%	0.00%	0.00%	0.04%	0.05%	0.08%

Source: Mendes (1994)

3.5.3 Impacts on Brazilian exports

An exercise was carried out in order to identify the potential impacts of emission control costs on the competitiveness of Brazilian exports based on exports data from CHELEM.[12] Three destination areas were considered: European Union, NAFTA and Latin America. Table 18 presents the importance of the three selected regions for Brazilian exports.

Table 18. Brazilian Exports (US$ Millions, current prices)

Region	1980/84	1985/89	1990/94	1995/96
Latin America (excluding Mexico)	2993	3636	6655	10345
NAFTA	5581	8444	8757	9658
European Union	6390	8501	10774	12415
Total	22255	28911	36434	46429

Source: CHELEM

It can be seen that the three selected areas are responsible for most of the demand for Brazilian exports. Trade within Latin America is the most dynamic, mainly because of the Mercosul integration process. The diversification of exports is considerable, but the exports of basic and semi-manufactured goods are prevailing.

In order to obtain the trade deviation estimates, it is also necessary to determine how much demand would vary if prices are altered (the price-elasticity of demand for Brazilian export goods). There are only a few empirical studies on the subject, and almost none at the sector level.[13] Another problem is related to changes in trade patterns and macroeconomic conditions, particularly changes in the exchange rate that affect the system of relative prices, which has great importance for the evolution of exports.

In this report, the choice adopted was to use values close to the ones estimated by Cavalcanti *et al.* (1998) for the price-elasticity of the exports quantum - even though they are very aggregate, they were obtained in the same time period of the cost estimation. Cavalcanti *et al.* (1998) present two estimates of price elasticities, one for the semi-manufactured goods (-0.34) and another for the manufactured ones (-0.78). These values were then applied to the estimates of cost

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[12] Comptes Harmonisés surles Échanges et l'Économie Mondiale – databasis (??) on international trade organized by the Centre D'Études Prospectives et d'Informations Internatinonales (CEPII), Paris, France.

[13]IPEA is currently working on estimating these sector elasticities, but there were no results available at the time of concluding this report. The use of these elasticities in the future will considerably improve the quality of these estimates.

increases in each sector. Given the uncertainties in the exercise, a sensitive analysis was carried out assuming a minimum and a maximum value for all sectors. Hence, the estimation of trade deviation are presented under two scenarios: optimistic (elasticity of -0.34) and pessimistic (elasticity of -0.78). Tables 19 and 20 present the results in US$, and Tables 21 and 22 in percentage of the observed exports.

Table 19. Pessimistic scenario: export losses caused by emission control costs, US$ millions (current); elasticity: - 0.78

	1980/84	1985/89	1990/94	1995/96
Removal of 50% of emissions				
Total	154	255	366	467
Latin America	27	31	66	103
NAFTA	59	110	127	136
European Union	31	56	86	98
Removal of 75% of emissions				
Total	180	299	429	548
Latin America	32	36	77	120
NAFTA	69	129	150	161
European Union	36	66	101	115
Removal of 100% of emissions				
Total	333	555	790	982
Latin America	49	55	121	192
NAFTA	143	265	311	328
European Union	69	125	192	218

Table 20. Optimistic scenario: export losses caused by emission control costs, US$ millions (current); elasticity: - 0.34

	1980/84	1985/89	1990/94	1995/96
Removal of 50% of emissions				
Total	67	111	160	204
Latin America	12	13	29	45
NAFTA	26	48	55	59
European Union	13	24	37	43
Removal of 75% of emissions				
Total	79	131	187	239
Latin America	14	16	33	52
NAFTA	30	56	65	70
European Union	16	29	44	50
Removal of 100% of emissions				
Total	145	242	344	428
Latin America	22	24	53	84
NAFTA	62	115	136	143
European Union	30	54	84	95

Table 19. Pessimistic scenario: export losses caused by emission control costs, % of observed exports; elasticity: - 0.78

	1980/84	1985/89	1990/94	1995/96
Removal of 50% of emissions				
Total	0.7%	0.9%	1.0%	1.0%
Latin America	0.9%	0.8%	1.0%	1.0%
NAFTA	1.1%	1.3%	1.5%	1.4%
European Union	0.5%	0.7%	0.8%	0.8%
Removal of 75% of emissions				
Total	0.8%	1.0%	1.2%	1.2%
Latin America	1.1%	1.0%	1.2%	1.2%
NAFTA	1.3%	1.5%	1.7%	1.7%
European Union	0.6%	0.8%	0.9%	0.9%
Removal of 100% of emissions				
Total	1.5%	1.9%	2.2%	2.1%
Latin America	1.7%	1.5%	1.8%	1.9%
NAFTA	2.6%	3.1%	3.6%	3.4%
European Union	1.1%	1.5%	1.8%	1.8%

Table 20. Optimistic scenario: export losses caused by emission control costs, % of observed exports; elasticity: - 0.34

	1980/84	1985/89	1990/94	1995/96
Removal of 50% of emissions				
Total	0.3%	0.4%	0.4%	0.4%
Latin America	0.4%	0.4%	0.4%	0.4%
NAFTA	0.5%	0.6%	0.6%	0.6%
European Union	0.2%	0.3%	0.3%	0.3%
Removal of 75% of emissions				
Total	0.4%	0.5%	0.5%	0.5%
Latin America	0.5%	0,4%	0.5%	0.5%
NAFTA	0.5%	0.7%	0.7%	0.7%
European Union	0.2%	0.3%	0.4%	0.4%
Removal of 100% of emissions				
Total	0.7%	0.8%	0.9%	0.9%
Latin America	0.7%	0.7%	0.8%	0.8%
NAFTA	1.1%	1.4%	1.6%	1.5%
European Union	0.5%	0.6%	0.8%	0.8%

Some important conclusions are suggested by these results. Given the relatively low costs of environmental control, the estimated loss of exports is not high. The total loss would remain between 1% and 2% of the total value of exports. These figures are close to the ones obtained by Repetto (1995) in his analysis of the US industry, indicating that the costs of pollution abatement are not as high as argued by those against more effective environmental controls.

On the other hand, the impacts may be very differentiated in terms of sectors and destination markets. Some industries are more problematic, and the loss in the exports may reach considerable amounts in sector terms. The most important cases are footwear (loss of up to 15.8% in the pessimistic case, assuming 100% removal), non-ferrous metallurgic (maximum loss of 10.3%) and other metallurgic (maximum loss of 8.7%). The higher concentration of exports of these goods in some specific markets where buyers are more environmentally conscious may lead to more important trade losses. This is a typical case of the European Union - fortunately, this is a destination which receives goods less dependent on production activities with environmental liabilities. On the other hand, NAFTA receives the most concentrated basket of goods that require more expenditure in environmental control. If trade barriers based on environmental claims were accepted, exports to North America would face important restrictions.

One last comment refers to the possible impacts on imports. In the exercise, this impact was not considered, but it is very likely that imports would increase if the similar domestic goods become more expensive. This point is of very difficult estimation, but crucial to understand the potential impacts in terms of higher regional integration via Mercosul. The simultaneity between more rigorous emission standards in Brazil and the removal of trade barriers with its neighbours may lead to an increase in imports of the goods currently produced under worse environmental conditions. Even though the aggregate result may be of relatively minor dimension, localised impacts in terms of regions and/or sectors may result from the disparity between the relatively more rigorous standards in Brazil and the lack of environmental control in other Mercosul countries.

However, it is important to highlight the problems and limitations of these exercises. The results discussed above are entirely dependent on the reliability of the information on direct control costs, additionally to all other restrictions that were necessary in estimation of emissions. There are considerable problems to evaluate adequately the impacts of the differentiation of environmental control costs, including its own dimension. Control costs depend on the assimilative capacity of the environment (not considered in the exercise) as well as the level and composition of the economic activity. Moreover, only the end-of-pipe costs are usually available. Hence, this calculation may lead to unrealistic conclusions, since it neglects the importance of investment in new technologies and modern equipment, which are, at the same time, cleaner and more efficient in economic terms.

The point is that this approach ignores the role of innovations, which systematically changes the effective relationship between production and environmental control costs. This is associated to the so-called technological effect, which has not been considered in the analysis so far. The following chapter aims at exactly this point: once the dynamic process of environmental innovations is considered, the conclusions concerning trade and the environment may change completely.

4. Environmental innovation and openness in Brazilian industry

The previous chapters have discussed the relative specialisation of the export complex in “dirty” activities emphasising the so-called “composition effect”. However, the input-output analysis that has empirically supported this hypothesis is essentially a static approach, in the sense that it does not consider the technological changes in time. But many of the arguments in favour of the idea that openness has positive effects on the environment are exactly based on the argument that a better environmental performance is essential for keeping their competitiveness. This chapter discusses the issue of environmental innovation, trying to check if companies with global insertion (either because of capital ownership or trade flows) have a different behaviour when compared to nationally owned, domestic oriented ones.

The empirical evidence is based on data for the state of São Paulo obtained for the year using the PAEP/SEADE survey. This survey refers to the year 1996, reaching a total number of 43,900 industrial companies, from all sectors. The answers were voluntary, explaining the difference in the number of answers in each table.

The first hypothesis to be tested was that companies with global interests (at least part of its property is owned by foreigners) tend to adopt environmental innovations and to perceive the environment as business opportunities (thus with potential losses if inadequate environmental procedures are adopted) in a higher degree than the others.[14]

In the PAEP/SEADE questionnaire, the following variables were chosen to test if the firms are concerned with environmental issues:

Business opportunities – if the answering company considered that the development of environmentally friendly products and processes is a source of increasing its business activity. Possible answers: yes/no;

Environmental implications: market losses – if the answering company considered that its environment performance has resulted in the loss of markets, domestically or internationally. Possible answers: yes/no;

[14] In the PAEP/SEADE survey, companies with global interests were considered as the ones with capital ownership classified as foreign (100% of the capital is owned by foreigners) and national and foreign (at least one of the controllers is a foreigner).

Environmental implications: higher costs – if the answering company considered that the activities associated with its environmental performance have resulted in higher costs (investment in control measures, fines and levies, etc.). Possible answers: yes/no.

Tables 23 and 24 present the results from crossing the variables above with the origin of capital ownership. From the 843 companies with global interests (capital owned at least partially by foreigners), 52.4% believe that the development of products and processes less harmful to the environment may turn out to be a business opportunity. If the companies that are solely owned by foreigners are considered, the percentage of positive answers increases to 54.9%. Among the companies exclusively owned by nationals, the percentage drops to 29.2%. Therefore, this result confirms the hypothesis that firms with global interests are more inclined to foresee the environmental questions as business opportunities than the nationally owned ones.

Table 23. Firms that consider the environment as a business opportunity, according to their ownership, 1996

		BUSINESS OPPORTUNITY – ENVIRONMENTALLY FRIENDLY PRODUCTS AND PROCESSES		
FIRM'S CAPITAL OWNERSHIP (IN 12/31)	Data	1 = YES (A)	2 = NO (B)	Total (C)
1 = NATIONAL	Number Of Firms	11,702	28,367	40,069
	Percentages A/C And B/C	29.2	70.8	
2 = FOREIGN	Number Of Firms	322	264	586
	Percentages A/C And B/C	54.9	45.1	
3 = NATIONAL AND FOREIGN	Number Of Firms	120	137	257
	Percentages A/C And B/C	46.7	53.3	
Total No. Of firms		12,144	28,768	40,912
	Percentages A/C And B/C	29.7	70.3	

Source: Fundação Sistema Estadual de Análise de Dados - SEADE. Pesquisa da Atividade Econômica Paulista – PAEP 1996.

Nevertheless, only 11.4% of the companies with global interests admitted market losses because of the environmental effects of their activities. This percentage falls to only 4.3% for the nationally owned companies, and rises to 12.3% if the answers are restricted to the companies exclusively owned by foreigners. So, most of the answers (95.6%), independently of the origin of capital, pointed out that they did not perceive any losses in either domestic or international markets as a consequence of their actions to the environment.

Table 24. Firms that consider market losses caused by the environmental consequences of their actions, according to their ownership, 1996

		ENVIRONMENTAL CONSEQUENCES – MARKET LOSSES		
FIRM'S CAPITAL OWNERSHIP (IN 12/31))	Data	1 = YES (A)	2 = NO (B)	Total (C)
1 = NATIONAL	Number of firms	1,721	38,326	40,047
	Percentages A/C and B/C	4.3	95.7	
2 = FOREIGN	Number of firms	72	511	583
	Percentages A/C and B/C	12.3	87.7	
3 = NATIONAL AND FOREIGN	Number of firms	24	234	258
	Percentages A/C and B/C	9.3	90.7	
Total No. of firms		1,817	39,072	40,889
	Percentages A/C and B/C	4.4	95.6	

Source: Fundação Sistema Estadual de Análise de Dados - SEADE.
Pesquisa da Atividade Econômica Paulista – PAEP 1996.

Table 25 shows that 41.1% of the companies with global interests considered that their costs were increased because of environmentally related activities. This percentage is reduced to 14.8% for the nationally owned companies. In total, 84.7% considered that there were no cost increases because of environmental questions.

Table 25. Firms that consider rising costs caused by the environmental consequences of their actions, according to their ownership – 1996

		ENVIRONMENTAL CONSEQUENCES – RISING COSTS		
FIRM'S CAPITAL OWNERSHIP (IN 12/31)	Data	1 = YES (A)	2 = NO (B)	Total (C)
1 = NATIONAL	Number of firms	5,919	34,131	40,050
	Percentages A/C and B/C	14.8	85.2	
2 = FOREIGN	Number of firms	242	341	583
	Percentages A/C and B/C	41.5	58.5	
3 = NATIONAL AND FOREIGN	Number of firms	104	155	259
	Percentages A/C and B/C	40.2	59.2	
Total No. of firms		6,265	34,627	40,892
	Percentages A/C and B/C	15.3	84.7	

Source: Fundação Sistema Estadual de Análise de Dados - SEADE. Pesquisa da Atividade Econômica Paulista – PAEP 1996.

Concluding, nationally owned companies do not perceive the environmental issues in the same way as the companies with global interests, confirming the hypothesis previously presented. However, most of the companies did not consider market losses because of environmental protection measures, thus refusing another of the hypotheses previously discussed. Note that a better definition of companies with global interests would have to consider too the domestically owned companies which exports a considerable share of its production; it is possible that with this new classification the differences between the two groups of companies would become even greater.

The variables present in the survey chosen to reflect the adoption of environmental innovations were:

Factors motivating the company to innovate (from 1994 to 1996): environmental preservation –indicates the degree of importance given by the answering company to the strategy of environmental preservation as a motivation factor to innovate. Possible answers: indifferent, less important, important, very important, or crucial.

Investment: changes in the production process for environmental reasons (from 1994 to 1996). Possible answers: yes/ no.

Table 26 shows the crossing of the first variable with the origin of capital. The vast majority (85.5%) of the firms with global interests considers the strategy of environmental preservation as important, very important or crucial as a motivation factor for the company to innovate. This percentage falls to 78.4% for domestically owned companies. This shows that most of the companies are more inclined to innovate because of environmental questions, and that this behaviour is more evident in the companies with global interests.

Table 26. Degree of importance of the environment protection strategy as a factor which motivated the firm to innovate, according to their ownership – 1996

		FIRM'S CAPITAL OWNERSHIP (IN 12/31)			
FACTORS WHICH MOTIVATED THE FIRM TO INNOVATE – ENVIRONMENT PROTECTION (94-96)	Data	1 = NATIONAL	2 = FOREIGN	3 = NATIONAL AND FOREIGN	Total
1 = INDIFFERENT (A)	Number of firms	1,095	10	16	1,121
	Percentages A/F	14.7	3.3	14.8	
2 = LESS IMPORTANT (B)	Number of firms	518	22	12	552
	Percentages B/F	6.9	7.2	11.1	
3 = IMPORTANT (C)	Number of firms	2,361	113	22	2,496
	Percentages C/F	31.6	36.8	20.4	
4 = VERY IMPORTANT (D)	Number of firms	2,458	109	41	2,608
	Percentages D/F	33.0	35.5	38.0	
5 = CRUCIAL (E)	Number of firms	1,028	53	17	1,098
	Percentages E/F	13.8	17.3	15.7	
Total No. of firms (F)		7,460	307	108	7,875

Source: Fundação Sistema Estadual de Análise de Dados - SEADE.
Pesquisa da Atividade Econômica Paulista – PAEP 1996.

Table 27 presents the companies which invested or not in changes in the production process aiming at the reduction of environmental problems. Again, the companies with global interests showed a different behaviour, with 40.8% answering positively, against only 18.3% of the domestically owned companies. Therefore, it can be concluded that companies with global interests tend to be more prone to adopt environmental innovations than the domestically owned ones, even though most of the latter also consider the environment as an inducing factor to innovation.

Table 27. Firms that made investments in changes in their production processes for environmental reasons, according to their ownership – 1996

	FIRM'S CAPITAL OWNERSHIP (IN 12/31)			
INVESTMENT – CHANGES IN PRODUCTION PROCESSES	1 = NATIONAL	2 = FOREIGN	3 = NATIONAL AND FOREIGN	Total
1 = YES (A)	7,294	251	92	7,636
Percentages A/C and B/C	18.3	43.1	35.5	18.7
2 = NO (B)	32,674	331	167	33,173
Percentages A/B and B/C	81.7	56.9	64.5	81.3
Total of firms (C)	39,968	582	259	40,809

Source: Fundação Sistema Estadual de Análise de Dados - SEADE. Pesquisa da Atividade Econômica Paulista – PAEP 1996.

Another possible hypothesis is that innovative firms are the ones with highest investment in R&D. In other words, companies spending more resources in R&D are more inclined to adopt innovations, including the environmental ones. The variable chosen to reflect R&D efforts was "Internal sources for innovation activities, 1994 to 1996 – R&D department", indicating the degree of importance of the internal department of R&D as an induction source of innovation development inside the company. The possible answers were indifferent, less important, important, very important, or crucial.

Table 28 shows the proportion of companies that invested in changes in the production process aiming at the reduction of environmental problems, according to the importance attributed to their internal R&D department for the innovative behaviour of the company. The higher the importance of the R&D department, the greater was the proportion of companies that invested in changes in the production process to solve environmental problems. Thus, only 28% of the companies that declared indifference to internal R&D department invested in changes in the production process. This proportion rises to 49% for the companies that declared that their own R&D departments were crucial for the innovation process inside the firm.

Table 28. Firms that invested in changes in their production processes for environmental reasons, according to the degree of importance of their own R&D department – 1996

		INTERNAL SOURCES OF INNOVATIVE ACTIVITIES – R&D DEPARTMENT (94-96)					
INVESTMENT – CHANGES IN THE PRODUCTION PROCESSES	Data	1 = INDIFFERENT	2 = LESS IMPORTANT	3 = IMPORTANT	4 = VERY IMPORTANT	5 = CRUCIAL	Total
1 = YES (A)	Number of firms	242	193	1,277	789	380	2,880
	Percentages A/C	27.8	38.3	39.6	42.6	49.0	39.9
2 = NO (B)	Number of firms	629	311	1,945	1,063	395	4,343
	Percentages B/C	72.2	61.7	60.4	57.4	51.0	60.1
Total of firms (C)		871	504	3,221	1,852	775	7,223

Source: Fundação Sistema Estadual de Análise de Dados - SEADE.
Pesquisa da Atividade Econômica Paulista – PAEP 1996.

Table 29 shows the crossing of the degree of relevance attributed to preservation as a motivation factor for innovation, and the degree of importance of the internal R&D department. The results point out that there is an increase in the proportion of companies that consider relevant to invest in internal R&D activities according to the importance attributed to the environment as a motivation factor for innovations.

Table 29. Degree of importance of the environment protection strategy as a factor which motivated the firm's innovation according to the degree of importance of their own R&D department – 1996

	INTERNAL SOURCES OF INNOVATIVE ACTIVITIES – R&D DEPARTMENT (94-96)					
FACTORS WHICH MOTIVATE INNOVATION – ENVIRONMENTAL PROTECTION (94-96)	1 = INDIFFERENT	2 = LESS IMPORTANT	3 = IMPORTANT	4 = VERY IMPORTANT	5 = CRUCIAL	Total
1 = INDIFFERENT (A)	182	46	296	151	132	808
Percentages A/F	25.2	10.4	10.8	9.8	21.0	13.3
2 = LESS IMPORTANT (B)	49	56	164	111	65	447
Percentages B/F	6.8	12.7	6.0	7.2	10.4	7.4
3 = IMPORTANT (C)	221	157	933	337	137	1,784
Percentages C/F	30.6	35.6	34.1	21.9	21.8	29.4
4 = VERY IMPORTANT (D)	201	153	914	599	195	2,062
Percentages D/F	27.8	34.7	33.4	38.9	31.0	34.0
5 = CRUCIAL (E)	69	29	429	341	99	967
Percentages E/F	9.6	6.6	15.7	22.2	15.8	15.9
Total of firms (F)	722	441	2,737	1,539	628	6,067

Source: Fundação Sistema Estadual de Análise de Dados - SEADE.
Pesquisa da Atividade Econômica Paulista – PAEP 1996.

The results above confirm that companies investing internally in R&D are more able to generate or adopt innovations, including the ones destined to environmental issues. Companies attributing a higher degree of importance to their R&D departments are the ones with higher positive answers in terms of innovation in processes (carried out to reduce environmental damage), and perception of environmental restrictions as a motivation factor in the innovation process.

4.1 Export-oriented firms

In the previous section, it was shown that foreign owned firms have a better perception of the environmental issues than the ones owned by nationals. The objective of this section is to show that a similar trend is also true for export-oriented companies, independently of their capital ownership. In other words, the pressure for better environmental performance is clearer perceived in the companies that are more exposed to the global economy.

According to Table 30, the companies that have declared the environment as a business opportunity (instead of a restriction) tend to present a higher level of exports. The contrast is more accentuated for domestic owned companies, but the higher perception of the potential for “green” business is found among the foreign owned.

Table 30. Average % of exports over total sales, according to the origin of capital and the consideration of the environment as business opportunity

		Environment as business opportunity		
Origin of capital		Yes	No	Average % exports
Domestic	Average % exports	1,04	0,66	0,77
Foreign	Average % exports	9,40	8,94	9,19
National and foreign	Average % exports	7,39	5,99	6,64
Total Global		1,32	0,76	0,93

Source: SEADE/PAEP

Table 31 confirms that companies that admit the possibility of market losses because of environmental consequences of their activities are also more export oriented: the exports average of those who answered yes is more than the double for hose who answered no. The results of Table 32 point out, again, to the same direction: the firms which declared that they had costs in activities related to the environment present the higher proportion of exports in their total sales. Considering only the domestic owned companies, the export average of those who answered positively (2.03%) is almost four times the exports average for those who declared not having this kind of expenditure (0.55%). This difference is also significant for foreign owned companies.

Table 31. Exports over total sales according to the origin of capital and the effect of losing markets because of the environmental consequences of their activities

		Environmental effects: market losses		
Origin of capital		Yes	No	Average % exports
Domestic	Average % exports	1.47	0.74	0.77
Foreign	Average % exports	15.21	8.20	9.07
National and foreign	Average % exports	11.35	6.20	6.69
Total average % exports		2.14	0.87	0.93

Source: SEADE/PAEP

Table 32. Exports over total sales according to the origin of capital and the effect of increasing costs because of activities related to the environment

		Higher costs because of environmental activities		
Origin of capital		Yes	No	Average % exports
Domestic	Average % exports	2.03	0.55	0.77
Foreign	Average % exports	13.55	5.87	9.07
National and foreign	Average % exports	6.72	6.67	6.69
Total average % exports		2.55	0.63	0.93

Source: SEADE/PAEP

Finally, it is important to make some comments on sector differences. Table 33 shows, for each industry, the exports average according to selected variables: products and processes perceived as environmentally friendly; costs incurred because of environmental activities; investments in the substitution of contaminant inputs; and investments in process modification in order to reduce environmental stress. The answers are not homogeneous per sector, but in most sectors it was confirmed the referred relation between higher concern with the environment and more importance of exports in total sale. Some aspects that deserve attention: the questions where differences in the answer patterns refer to costs already incurred related to environmental matters in the sectors with higher export profile (footwear; motor vehicles; machinery and equipment, pulp and paper), the difference between the average export proportion among firms is considerable among firms declaring concern with environmental issues and the ones declaring the opposite - the most important exception to this pattern of answer refers to petroleum refineries and alcohol distilleries.

Table 33. Environmental perception and exports over total sales, per sector

	Environment as business opportunity		Higher costs because of environmental activities		Investment in the substitution of pollutant inputs		Investment in environmentally friendly processes	
Sectors	Yes	No	Yes	No	Yes	No	Yes	No
Mineral extraction	0.66	0.15	0.40	0.39	0.12	0.43	0.49	0.31
Refineries & alcohol dist.	3.40	3.80	3.05	4,.82	1.21	5.15	1.04	5.44
Chemical products	1.86	2.21	3.07	1.47	2.89	1.67	2.92	1.54
Rubber and plastic products	0.56	0.33	0.98	0.31	0.79	0.34	0.57	0.37
Non-metallic minerals	0.57	0.81	1.53	0.59	2.46	0.53	1.88	0.52
Metallurgy (basic)	1.38	0.37	1.57	0.45	1.18	0.53	0.94	0.59
Metallic products (excl. machinery and equipment)	0.72	0.44	1.38	0.34	1.31	0.38	1.15	0.35
Pulp and paper	1.45	0.54	2.50	0.50	3.19	0.38	2.67	0.42
Food and beverages	1.70	0.64	2.86	0.42	3.76	0.59	2.63	0.50
Textiles	1.46	0..50	1..54	0.56	1.93	0.54	1.70	0.55
Wearing apparel	0.04	0.13	0.15	0.11	0.09	0.11	0.05	0.12
Leatherwear	5.53	2.23	16.40	1.64	8.22	2.25	12.81	1.86
Machinery and equipment	2.54	1.97	5.00	1.72	5.13	1.53	3.49	1.81
Machinery for offices/computers	0.00	0.84	10.87	0.10	4.71	0.11	6.92	0.11
Electric equipment	1.14	1.05	2.52	0.91	2.61	0.79	2.04	0.86
Electronic and communications material	2.62	0.90	2.92	1.26	3.04	1.13	1.92	1.36
Medical equip., optics, industrial automation	3.12	2.59	4.83	2.56	2.60	2.78	2.79	2.75
Motor vehicles	3.49	1.91	6.81	1.38	4.89	1.67	4.80	1.75
Other transportation equip.	1.06	2.84	6.97	1.42	4.96	1.95	2.25	2.39
Other industries	0.50	0.53	1.04	0.44	0.89	0.47	0.80	0.47
Total	1.32	0.76	2.55	0.63	2.49	0.67	2.00	0.68

Source: SEADE/PAEP

The survey confirmed the hypothesis that firms with global interests are the most prone to adopt environmental innovations, even though most of the nationally owned companies or domestic oriented also consider environmental issues as a motivation factor to innovate. This counterbalances the previous sections, in the sense that shows that the process of opening the economy has some environmental advantages, as theoretically argued by many.

The results of these input-output exercises, using constant coefficients for industrial emissions, showed that the production chain associated with Brazilian industrial exports is more intensive in emissions than the production chains oriented towards domestic markets. This trend was observed for most of the pollution parameters analysed, despite the diversity of sources for the emission coefficients, suggesting that the Brazilian industry has been relatively specialised in the supply of potentially pollutant goods to the international markets. This result is, thus, compatible with the hypothesis that developing countries tend to concentrate on “dirty” industries that become less competitive in developed countries because of tighter environmental controls.

This process was, nevertheless, counterbalanced by the emissions “savings” created by the fast expansion of imports during the 1990s. The avoidance of emissions associated with the import goods, however, could have been greater if rising industrial imports were not concentrated in relatively clean activities, particularly those with higher intensity in technology (electronics, for example), while the structure of industrial exports remained associated with more emission intensive sectors (mainly semi-manufactured and intermediate goods).

Another important result was that the direct costs of introducing environmental control strategies are relatively low, considering the industry as a whole. However, since these costs vary widely among sectors and destination markets, the impacts of introducing pollution abatement measures may be considerable in some specific industries, damaging their competitiveness. The highest risks of losing markets are in the footwear, non-ferrous metallurgic and other metallurgic industries and, in regional terms, the exports destined to the NAFTA region.

The static nature of input-output exercises, however, does not allow capturing the so-called technological effect, which is essentially dynamic and very difficult to measure and model. The PAEP survey, obtained from industries in the State of São Paulo, showed that firms with international insertion tend to be more concerned with environmental issues, to invest more in “cleaning” their production processes, and to perceive the competitive advantages of environmental innovations. This is associated with higher environmental standards and pressures in international markets, thus being compatible with the hypothesis that the trade and capital openness process tend to encourage the adoption of environmentally sound practices and products.

These results have important implications for policy making. First of all, it is clear that the relatively high concentration of Brazilian industrial exports in pollution-intensive activities makes these exports very sensitive to the issue of environmental barriers to trade. If there is a change in the institutional framework regulating international trade towards the acceptance of environmental criteria for import control, as advocated by many environmentalist organisations in developed countries, there could be important losses to Brazilian industrial exports. There are two possible strategies to deal with this problem:

a) to adopt an aggressive position against the proposed changes in trade regulations, maintaining the *status quo* of none/very restricted environmental barriers in the international trade agreements; and/or

b) to enhance the environmental performance of Brazilian industries, either improving local emission standards or changing the composition of industrial exports, becoming less dependent on exports associated with "dirty" production chains.

Even though these strategies are not contradictory, they reflect different perspectives. The option (a) reflects a view that the claims for environmental restrictions in trade (and capital) flows are a short-term pressure that will not be approved in the future. However, one possible problem that may emerge in the forthcoming years is that, with the deepening of regional trade agreements such as Mercosul and possibly the American Free Trade Agreement, Brazilian producers could face competition from the exports from neighbour countries which are subject to much less environmental controls, since Brazil is a leader in Latin America in terms of environmental controls. This would be a reversal of the present situation, and in that case the Brazilian producers could be the losers if no standardisation of environmental controls are adopted.

Therefore, the second strategy seems to be a better way to deal with the problem in the long term. There is a smooth but consistent change in the perception of Brazilian policy makers towards the adoption of economic instruments in environmental management, based on the user/polluter-pays principle, and as a consequence some sectors may present short-term losses in their competitiveness. But the good news the results above show are that this overall cost increase may be considerably less than usually thought (with the exception of some specific sectors, that could receive special compensation policies during the transition to cleaner production), and that many firms are already searching voluntarily for better environmental procedures. This is another important feature of international trade that counterbalances the original problem of specialisation in emission intensive activities: the pressures of consumers in developed countries are “reaching their target”, in the sense that export-oriented and/or foreign-owned firms tend to see the potential gains from adopting environmental innovations in a different way than firms that are not exposed to these pressures.

However, this transition towards a more environmentally sound economy cannot rely on a *laissez-faire* belief that the simple exposition of Brazilian firms to the market will be a move towards the desired situation. One important step is the already referred push for economic instruments for environmental management, allowing flexible but efficient measures to improve environmental standards. This must be combined with industrial policies aiming the spread of win-win environmental innovations (energy and other inputs savings; better access to markets, particularly in developed countries; higher quality and efficiency standards associated with changes in processes associated with environmentally-friendly measures; etc.). Some examples of these policies are the strengthening of the firm to absorb and generate environmentally related technologies; investment in human capital at the basic and professional levels; reduction in the regional differences in environmental performance; and incentives to certification and domestic consumers’ perception of the benefits of environmentally sound products and processes, creating a domestic market for “green” products.

A final comment refers to the limitations of the empirical exercises because of data quality and methodological problems. This indicates the urgent need for improvements in the gathering and systematisation of environmental indicators and statistics concerning industrial pollution.

The golden age of industrialisation in Brazil (1950s, 1960s and 1970s) has resulted in fast economic growth and structural changes in the productive structure. Nevertheless, the social and environmental consequences of this process were far from desirable. There is already a considerable amount of studies on the social exclusion in the Brazilian industrialisation process, but the consequences to the environment are yet to be researched in detail. The expansion of industrial activities were not followed by the establishment of pollution control authorities: the first environmental agency (FEEMA, in the State of Rio de Janeiro) was created only in 1977, when the industrialisation process was already losing its momentum and the rates of investment and output growth rates were declining from their historical averages. Indeed, the first effective national environmental law was created only in 1981. The pollution consequences of this lack of standards and mitigation procedures were dramatic, as exemplified by the tragedy of Cubatão industrial area (in the state of São Paulo).[15] Therefore, the shift towards more inward-oriented development has not resulted in improvements in the environmental question.

One point that is usually misunderstood is to consider that, during the import-substitution process, export-oriented policies were not important. Exports played a major role for financing the industrialisation process, which was intensive in imports, particularly machinery and intermediate inputs. For instance, the II National Development Program (1975-79), a crucial stage to complete the industrial structure, included among its main targets the expansion of export capacity in intermediate goods, such as metallurgy, petrochemicals, and pulp and paper. Providing fiscal and credit incentives to these sectors, characterised by their high consumption intensity of energy and other natural resources, has created a pattern of high emission activities that has considerably affected the Brazilian industrial export capacity. The environmental consequences of this shift in the export structure towards more energy (and pollution) intensive goods are discussed along this study.

An important shift towards trade liberalisation and privatisation has occurred in the 1990s. Import barriers were lifted, there were legal changes in order to ease foreign investment and the process of economic integration within the South American free trade agreement (Mercosul) gained speed. The impact of these measures has been concentrated mainly in deregulation and the increase of imports, particularly because of the overvaluation of the exchange rate after the Real economic plan (1994). Measured in terms of proportion to the GDP, there was no significant improvement in the export level, or the sum of exports and imports. But other changes can be more easily identified: industrial output increased but industrial employment fell. The environmental changes associated to these transformations are analysed in the next sections.

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[15] In the mid-1980s, 320 sources (related to 116 industrial) units were emitting around 400.000 tons of pollutants annually in Cubatão. The consequences to human health were dramatic: Cubatão had the highest rate of child mortality in the state of São Paulo (72/1000) despite generating more than 3% of the country's GDP, and 18% of the local population was suffering from respiratory diseases. Vila Parisi, the village around the industrial complex, was nicknamed "the Death's Valley". However, it was the very high level of fetus malformation and other problems for newborns ("the children of pollution") that caught more attention from the public opinion (Almeida 1997).

In summary, the environmentalist's position is strongly influenced by the past and present consequences of international trade in Brazilian history, which has (?) plenty of examples when natural resources depletion and degradation were a hidden cost of increasing exports. Therefore, they tend to be very sceptical about the argument that the future is not necessarily a reproduction of the past and that, under certain ideal conditions (full implementation of property rights, in order to solve market failures, and the correction of public policies which encourage the overexploitation of natural resources), improvements in trade relations will not represent an additional threat to the environment. Indeed, they tend to consider that these policy reforms are either unrealistic to be implemented under the social and political structure of Brazil, or, even worse, they would result in further harm to the environment - since the economic groups that tend to benefit with trade expansion are not concerned with the social and environmental damages caused by it. Nevertheless, their refusal to accept both the outward-looking model imposed by globalisation, and the inward-looking economic growth experienced in the industrialisation period (also harmful to the environment), has not yet been accompanied by feasible policy suggestions.

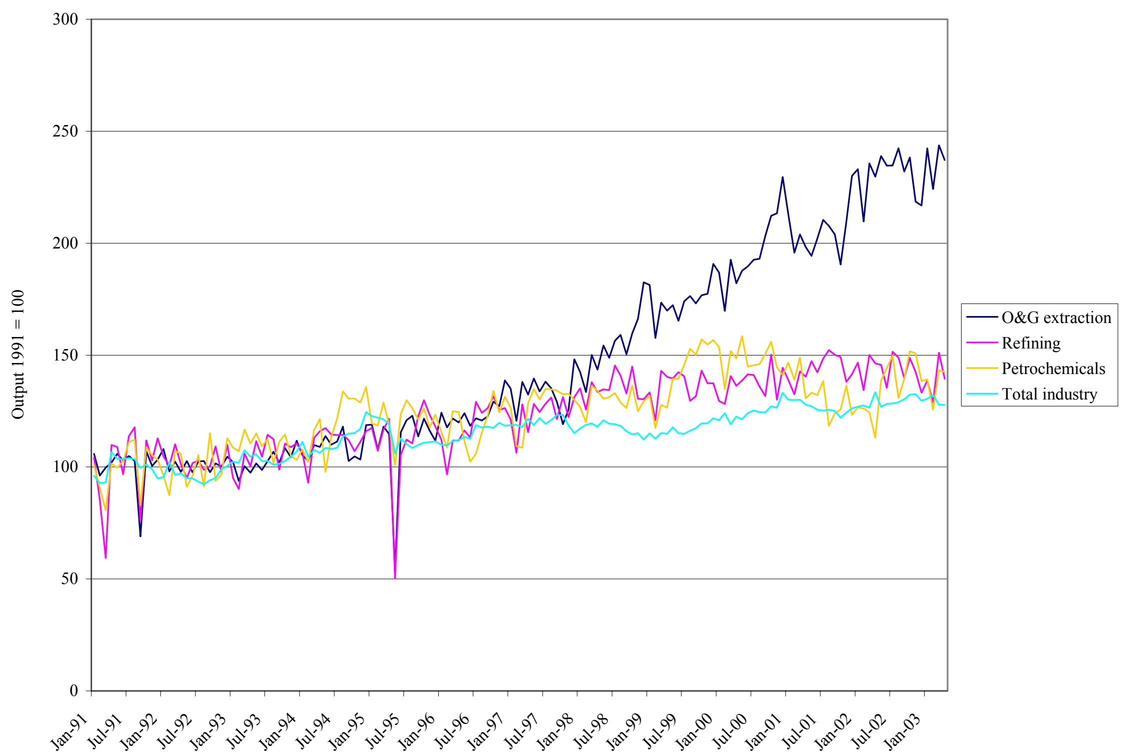
5. Natural resources and the Brazilian oil and gas sector

5.1 Introduction

The expansion of the energy sector is crucial for economic development. However, there are many potential problems related to it, including environmental degradation and the consumption of non-renewable resources. The oil and natural gas (O&G) industry is not an exception to this rule, and the challenge for sustainable development is to propose practical measures that would improve the existing practices in order to guarantee better material conditions without the worsening of the environmental conditions.

The O&G industry has been one of the most dynamic in Brazil in recent years. Figure 2 shows that O&G extraction has consistently grown above the total industrial output, while the oil refining and the petrochemical activities have followed the average industrial output. It is expected that the expansion in exploration, exploitation and processing activities will continue during this decade, with important (and positive) macroeconomic and sector impacts.

Figure 2. Output growth: O&G extraction, oil refining, petrochemical industry and total industry, Brazil, 1991-2002 (1991 Output = 100)



Source: Brazilian Institute of Geography and Statistics (IBGE)

However, the O&G industry is also characterised by the potential damaging effects of its activities. This chapter examines some of the impacts of the O&G expansion on the natural resource basis. Section 5.2 discusses the depletion of oil and natural gas reserves issue of depletion and exhaustion in Brazil. Section 5.3 presents the most important pollution problems related to these activities. Section 5.4 presents the results of an empirical exercise that estimates pollutant emissions from the current and future upstream and downstream activities, using an input-output model combined with fixed emission coefficients. Section 5.5 discusses future trends in environmental regulation for the sector.

5.2 Depletion, exhaustion and "green" accounting

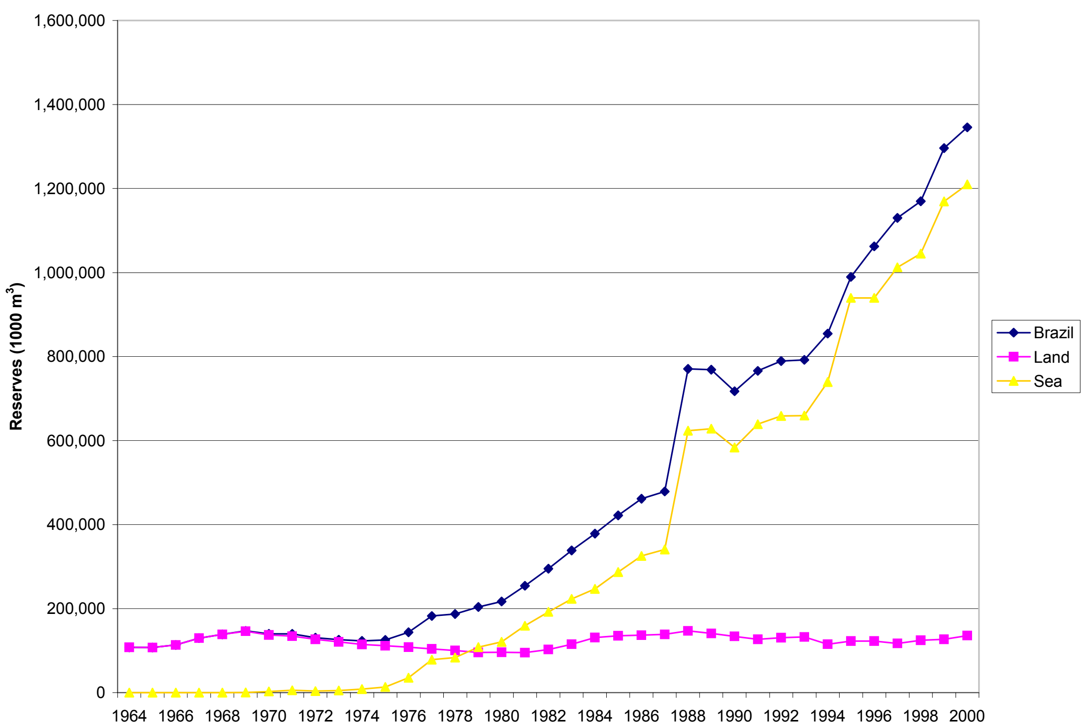
The economic consequences of an eventual ending of exhaustible natural resources, mainly fossil fuels, has been a polemic matter for a long time. Most of the mainstream economists believe that the market reacts to the signals of growing scarcity, through higher prices or technological change, endogenously creating the elements needed to a transition towards new sources of energy. The increasing scarcity would induce an appreciation of the value of the natural resource, therefore leading to its more rational use.

Moreover, higher prices for a scarce natural resource would lead to more research and development in both supply (new exploitation and exploration techniques) and demand (more efficient use or development of man-made inputs that substitute the vanishing resource). In both cases, the final effect is to impede that demand grows above supply, avoiding simultaneously the appreciation of the natural resource and its exhaustion.

The vision above is criticised by those who consider that is an excessive optimism concerning technical progress and the human capacity of substituting natural resources. This position dates back to the "limits to growth" hypothesis (the famous report by Meadows *et al.*, 1972) and is deeply rooted among those who consider that natural resources have unique properties, of difficult or even impossible replacement by human actions. Therefore their consumption implies some degree of irreversibility, reducing the availability of current resources for the future generations – by definition, a non-sustainable situation. According to this vision, the fact that new reserves are being incorporated in the production frontier does not represent a solution for the problem, but only slows it down.

In the case of oil and gas reserves, it is impossible to refute any of the opposing hypothesis above based on existing data. In the short run, there is no reason to believe that an eminent collapse of extraction will result from increasing depletion. In the Brazilian case, the main reason for that is the exploration efforts that resulted in new extraction fields, mostly offshore, which is also associated with technological breakthroughs that allow production in deep sea water. Additionally, new optimisation technologies are allowing the reopening of fields that were previously considered as exhausted (for example, in the Recôncavo region, in the state of Bahia), with positive impacts on supply. The continuous process of discoveries (Figure 3) has counterbalanced the growing volume of output, maintaining the ratio between annual extraction and known reserves at a relatively constant pattern, between 10 and 20 years.

Figure 3. Brazilian oil reserves, 1964-2000, 1000 m^3



Source: National Petroleum Agency (ANP)

However, there is no definitive guarantee that scarcity will not become a major issue in the long run, thus limiting future economic activities. Moreover, it is wrong to consider “extraction” of an already existing good as “production”. This creates an illusion of enrichment, overestimating the wealth created in the exploitation of non-renewable resources.

In the economic literature, this problem has encouraged academic studies intending to correct the National Accounts System (SNA) that does not acknowledge the problem of natural resources depletion. Known as “green accounting”, their objective is to estimate the monetary loss of natural assets (in this case, O&G reserves) and to include it among other costs associated with production and consumption.

In the conventional SNA estimates, value added is calculated as the difference between the gross value of output and intermediate consumption. The latter constitutes the expenditure on inputs and industrial operations and other present expenditures but excludes payments to production factors (labour and capital, broadly defined). The consumption of mineral reserves is not included in the total asset balance but, theoretically, the monetary value of the decrease in the stock of mineral assets must be subtracted from the receipts obtained by the possessor. This implies that the conventional accounting procedure can only be considered sound if resources are infinite, a hypothesis far from reality.

An amendment of the SNA is required to fix this problem. Nevertheless, various controversies emerge when concrete proposals of how to do it are presented.

For mineral resources, there are two competing methodologies to adjust the conventionally measured income and value added. Both depart from the same principle: according to the economic theory, the asset price should be equal to the present value of the net revenues one can expect to receive from the most efficient use of the resource .

$$V_t = \sum_{\tau=0}^{n_t-1} \frac{1}{(1+d)^{\tau}} \cdot p_{\tau} \cdot q_{\tau} \quad \mathbf{1}$$

where V_t is the present value of the asset at (initial) time t, n_t is the expected period of extraction at time t, d is the discount rate, p_{τ} is the expected unit rent (the difference between revenues and costs per unit of resource) at (future) time τ , and q_{τ} is the expected amount of resource to be extracted at time τ

Where the two models differ is in their treatment of expectations about future economic rents (per unit of output). The net price approach assumes an optimal extraction path, with unit rents rising by the Hotelling efficiency rule. In contrast, the user cost method assumes that future unit rents will be equal to current values.

This is a breakdown with the neoclassical theoretical perspective that has intended to reconcile the resource accounting problem with optimal control modelling (Hartwick and Hageman 1993). Future values for the expected variables described above are determined in a way that welfare, measured as discounted social consumption, is maximised. However the usual assumption of perfect foresight of the future in an ideal market where a Hotelling-like rule is fully observed, and the requirement of estimates of marginal product and costs, undermine the application of this theoretical contribution in most real world situations.[16]

Furthermore, in the net price method the Hotelling rule is not properly applied since it is net price (price minus average cost) and not the true rent (price minus marginal cost) which is considered. The use of the average net price as a proxy would thus only give strictly valid estimates of net domestic product if there were constant returns to scale in extraction.

Young and Seroa da Motta (1995) propose that the net price approach presents results that are identical to a particular case of the user cost approach when the discount rate is zero or depletion implies immediate exhaustion of the resource.

In formal terms, the user cost approach is equivalent to assuming that unit rents and extraction levels are not expected to vary in equation (1):

$$V_t = p_t \cdot q_t \cdot \sum_{\tau=0}^{n_t-1} \frac{1}{(1+d)^{\tau}} \qquad \mathbf{2}$$

[16] It is important to note that the Hotelling rule is a maximum-efficiency condition, but not a forecasting procedure. The confusion between maximum-efficiency and forecasting appears in the argument that economic analysis is possible only if agents are optimizing according to the Hotelling rule (Hartwick and Hageman 1993, p.222). The essential assumption for resource accounting (and economic theory) is that every agent individually intends to maximize their income given their own expectations. The absence of a reconciliation mechanism (such as the "social planner") turns the compatibility of all individual plans a matter of chance. Therefore a rational agent does not price his resource at a hypothetical value which would maximize social welfare if all the other agents did the same. The stock owners simply value the price according to their own expectations of income maximization, and experience has shown that the Hotelling rule may not be the wisest way of predicting the future (see, for example, Slade 1982).

The depletion cost is given by the discounted value of the expected loss of (net) revenue when the resource becomes exhausted (i.e., after n_t periods of time):[17]

$$DEP_t = -\Delta V_t = p_t \cdot q_t \cdot \frac{1}{(1+d)^{n_t}} \qquad \mathbf{3}$$

Note that the result is very sensitive to both the discount rate (d) and the depletion period (n). High values of either variable result in low estimates of user cost. The methodology thus reflects the real scarcity of the resource, since deductions from conventional production values are significant only if the actual rate of extraction implies the imminent exhaustion of the resource. The net price approach, on the other hand, requires that all of the surplus obtained from an exhaustible resource is deducted from income, irrespective of the availability of that resource.

Therefore, the net price approach can be considered as a special case of the user cost approach if either the depletion period or the discount rate are considered zero.[18] The first case (n=0) means that extraction represents immediate exhaustion of the resource. The second case (d=0) is consistent with the "intergenerational equity" argument (Price 1993). In both cases changes caused by revaluation or discoveries cannot be incorporated in the user cost, which becomes identical to the total rent. Therefore, the sustainable income is defined exclusively by the cost of production factors (labour and capital) involved in the extraction. This leads to the paradoxical situation where the sustainable income (per unit of mineral) increases only if extraction becomes more costly. In practical terms, the exclusion of all rents received in the mining activity removes any advantage of countries with mineral deposits over those who do not have that benefit (an "income edge", according to El Serafy 1989, p.13).

The advantages of being more general do not eliminate the uncertainty problem. The extreme simplicity of its treatment of rent expectations is clearly unrealistic. Indeed, the major criticism of the approach is the absence of a clear statement as to why expected user cost should be constant when prices and

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[17] Young and Serôa da Motta (1995) use an alternative expression, based on the opportunity cost of capital rather than the intertemporal discount rate.
[18] Note also that both methods assume perfect substitutability between natural and produced assets, from an accounting perspective.

extraction costs may vary over time.[19] Furthermore, the results are strictly dependent on the choice of the discount rate. Since there is no consensus about the proper discount rate to be adopted, a sensitive analysis assuming different values for (d) is the only way to produce empirical results.

This procedure was adopted by Young *et alli* (2000) in order to estimate the depletion cost of oil and natural gas reserves in Brazil. The results are presented in Table 34.

Table 34. Conventional and adjusted income, Mining Industry, Brazil, 1990-95, R$

Year	Conventional income	Rent	Adjusted Income d = 0%	Adjusted Income D = 5%	Adjusted Income d = 10%
1990	3.576.479.007	1.835.417.245	1.741.061.762	3.067.116.253	3.444.999.821
1991	3.594.354.052	1.737.413.880	1.856.940.172	3.006.582.678	3.453.219.572
1992	3.179.946.904	1.490.309.864	1.689.637.040	2.847.006.813	3.129.795.840
1993	2.953.931.407	1.313.375.528	1.640.555.879	2.745.926.036	2.952.696.261
1994	3.215.948.173	1.446.994.384	1.768.953.789	2.813.734.651	3.181.936.405
1995	3.122.779.254	1.298.146.981	1.824.632.273	2.847.016.647	3.106.737.635

Source: Young et alli (2000)

These results show that the “true” GDP of the O&G sector in Brazil would be considerably different from the conventional estimate. Under the most pessimistic scenario (d = 0%), the adjusted GDP would be about half of its conventional measurement. Hence, there is a considerable overestimate in the sector’s capacity to add wealth to the country - it increases the stock of produced assets, but at the expense of reducing natural capital.

5.3 Degradation problems

Pollution problems in coastal and open sea exploration and production (E&P) are caused by discharges resulting from routine activities and accidental events. The concentration of staff and equipment in certain localities that operate as support for the offshore platforms also create local environmental pressures, given the fast expansion in the urban population and the economic activities directly and indirectly generated, often without the adequate investments in sanitation, housing and other infrastructure requirements.

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[19] Another criticism, from a more neoclassical point of view, is that the extraction path assumed in the user cost approach is sub-optimal with respect to the Hotelling efficiency condition. The latter point of view assumes the existence of an optimal extraction path that can be derived from the present until the end of the planning period, i.e. the future can be perfectly foreseen. In reality, uncertainty about the future can lead to the rationale selection of alternative extraction paths. It must be remembered that the

The transportation of oil and gas from the platforms to the shore also involves environmental risks. The installation of pipelines requires systematic inspection, particularly concerning corrosion, to avoid spills. The construction of the pipelines results in the suspension of sediments from the seabed, altering marine habitats, especially if chemical residuals have been accumulated over time (for example, in bays or coastal areas near petrochemical poles). The separation of dejects pumped through the pipelines results in residuals that need to be discharged in appropriate places. Another impact is on fishing, since nets must be avoided where pipelines are installed.

The issue that has caught more attention from environmentalists and the public in general concerns accidents. Spills are frequent in exploration and transportation, being more serious for oil than gas. Another important factor refers to the ecological conditions where the accident happens. The damage is much worse it occurs in protected areas (such as bays or protected waters) and/or in areas of high importance for biodiversity or tourism. Internationally, accidents such as the Exxon Valdez, in Alaska in 1989, resulted in important changes concerning safety and prevention measures, and emergency procedures to avoid the dispersal of the oil. In Brazil, its equivalent in terms of public opinion outrage was the much more recent event in 2000, when a pipeline from Petrobras leaked several tons of oil in Guanabara Bay, a tourist postcard for Rio de Janeiro and Brazil.

Finally, an issue that has received more attention since the mid-1990s is the decommission of platforms after the halting of their operations. The problems faced by Shell when it released its decision to sink the Brent Spar platform in the North Sea resulted in a ferocious boycott campaign against the company in Western Europe, led by Greenpeace, forcing the company to reverse its decision and decommission the platform in shore. Even though there was a fierce debate about which option was the most damaging to the environment, the message was clear: there would be increasing pressure concerning the abandoned platforms and equipment in the oceans. Most countries are already adapting their environmental regulation to deal with this issue, but only the UK has already accomplished a framework regulating this issue.

The environmental problems of inland E&P are more complex than those from offshore because of the smaller assimilative capacity of the terrestrial and fluvial

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Hotelling condition is merely one of portfolio efficiency; it is not a forecasting system.

environments. The generation of mud, sediments, liquid discharges and other residuals require adequate procedures in order to avoid that their disposal affects the quality of land soils and water bodies in the proximity. The construction of pipelines is also more complex, with an extensive list of risks: soil erosion and instability, changes in water flows and effects on rivers, lakes and dams, disturbance in the fauna and flora, interference on migration routes, invasion by exotic species or by human settlers.

Ruptures and spills may lead to explosions and fires that, in inhabited areas, may risk human lives, requiring the maintenance of exclusion zones along the pipelines. If these exclusion areas are not enforced, they may result in illegal, disorganised occupation, such as *favelas*, with a serious risk of tragic accidents, such as the one in Vila Socó, Cubatão, state of São Paulo, when the explosion of a gasline resulted in many deaths. In forest areas, pipelines may result in paths that facilitate the penetration of settlers in areas previously protected, favouring migration and deforestation. This is the most frequent argument used by environmentalists to oppose the pipeline linking the Urucu fields to the main cities in the Brazilian Amazon: the length of the pipeline (420 km) is considered too extensive for a proper enforcement of the exclusion zone, and they forecast its use as a road by loggers, ranchers and settlers, endangering one of the best preserved areas of Amazonian rainforests.

However, the alternative of fluvial transport is also risky. The probability of accidents is considerable (particularly in areas where the riverbed changes frequently, such as in the Amazon), and the natural capacity of dispersal very reduced. Therefore, because of the smaller assimilative capacity, accidents in hidroways and rivers have potential effects even more serious than those happening in the open sea.

Environmental problems are not restricted to the E&P stages. Consumption of O&G products is also problematic. The intensive use of fossil fuels in the transportation sector causes many emission problems, ranging from local pollution (emissions of particulate matter, carbon monoxide, sulphur dioxide and other hazardous substances) to global warming (mainly from carbon dioxide).

There are also adverse environmental impacts from the use of fossil fuels to generate electricity: air pollution and global warming (mainly from emissions of SO_x, NO_x, CO, CHO, particulate matter and CO_2), water pollution (heavy metals and toxic substances) and sound pollution. The intensity of the impact depends on the choice of fuel, technical aspects of the machinery being used and geographical characteristics of the plant site (such as wind and topography). The burning of solid fuels, such as charcoal, tend to generate more residuals than oil, and natural gas burning is the option with the least pollutant emission.

The use of lubricants and other substances that generate water discharges or solid waste may affect rivers and waterbodies nearby. The use of water for refrigeration can be done with minimal impacts if the water is cooled before it is dropped back to the environment (otherwise it may damage plants and animals). The monitoring of discharge spills must be a constant concern because of their toxicity. Finally, the issue of noise must be considered if the unit is located near human settlements.

One very important feature that is receiving increasing attention by policy makers is that there are important environmental advantages of burning natural gas instead of other fossil fuels. Because the combustion of gas is more efficient and clean, the emission of residuals is smaller. Therefore, in areas where power was already being obtained by fossil fuel combustion, the conversion to natural gas represented an advance in terms of emissions per unit of available energy. This improvement is higher when the power plants are old, so with much lower levels of efficiency and emission control.

5.4 An input-output analysis of the environmental impacts of the oil industry in Brazil

As shown in the previous subsection, the potential for environmental problems in the O&G sector is considerable. However, there are no consistent statistics for the environmental impacts of the sector, particularly for non-accidental emissions. Given the high profile of major accidents, there is some information on the extension of their damages. In contrast, there is almost no data on emissions caused by routine activities. Considering that it is expected a major expansion of the O&G activities in the near future, the objective of this section is to estimate the expected increase in emissions in the sector.

5.4.1 Methodology

The analysis is based on the input-output model, already described in section 3.2. The choice of the baseline year was based on the fact that the latest IBGE input-output available was estimated for 1996. However, future trends of emissions were projected according to investment scenarios projected by Kupfer *et alli* (2001), simulating the direct and indirect effects of the increase in O&G production (upstream and downstream) and from the investments required for it.

The exercise is subject to the same methodological limitations of the input-output approach described in chapter 3. Probably the most important of them is the impossibility of anticipate accidental events, which are particularly important in the "midstream" stage (transport), and improvements in the emission abatement capacity resulting from investments and technical progress in environmental control. For the same reason, the model does not capture the consequences of decommissioning old platforms after their operations are stopped.

The emission coefficients used in these simulations were extracted from the *Industrial Projection Pollution System* (IPPS), elaborated by the World Bank (Hettige et alli, 1994). As discussed in subsection 3.3.2, although the IPPS estimates are not measurements of actual emissions in the Brazilian industry, they can be useful as a guideline in order to rank industrial sectors in terms of its potential emissions.

The IPPS pollutant coefficients used were based on the value of production (shipment value), lower bound, and refer to the following parameters:

- Air pollutants: sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), volatile organic compounds (VOC), fine particulate matter (PM) total particulate matter (TP), metals.
- Water pollutants: biochemical oxygen demand (BOD), total suspended solids (TSS), and metals.
- Land pollutants: metals.

5.4.2 Results

The first exercise was to estimate the current emission potential of the oil sector in the upstream (extraction) and downstream (refining and petrochemicals). Table 35 summarises the main results:

Table 35. Emissions from oil extraction and refining, Brazil, 1996

Parameter	Emissions, oil and natural gas exploitation (t)	Emissions, oil refining and petrochemicals (t)
Water		
BOD	61.688	177.383
TSS	3.349.553	2.251.967
Metals (water)	599	2.095
Air		
SO_2	843.722	7.385.761
NO_2	406.736	5.537.848
CO	889.342	4.059.338
VOC	259.825	4.418.879
Fine particulate	152.180	164.659
Particulates total	194.009	988.491
Metals (air)	4.069	4.725
Land		
Metals (land)	101.342	110.906

Source: Own elaboration, using IBGE data and IPPS coefficients

Then, similar estimates were produced for the emissions in the other industrial sectors. A ranking of the most pollutant industry was obtained with the relative position of each activity (position 1 referring to the most pollutant). Table 36 presents the relative position of O&G extraction and oil refining and petrochemicals in the ranking of most pollutant industries.

Table 36. Ranking of O&G extraction and oil refining and petrochemicals, Brazil, 1996

Parameter	Pollution ranking, oil and natural gas exploitation (42 sectors)	Ranking, oil refining and petrochemicals (42 sectors)
Water		
BOD	39	15
TSS	19	23
Metals (water)	32	10
Air		
SO_2	36	4
NO_2	36	3
CO	11	11
VOC	36	1
Fine particulates	27	22
Particulates total	34	11
Metals (air)	18	16
Land		
Metals (land)	21	17

Source: own elaboration, using IBGE data and IPPS coefficients

The results show that oil related activities have a high pollution potential, particularly the downstream ones (refineries and petrochemicals). This sector is responsible for the highest potential emission of VOC, and the rankings for NO_2 (3^{rd}) and SO_2 (4^{th}) are very high too. Other pollutant emissions that deserve attention are metals (water, air and land), CO, BOD and total particulate matter.

The upstream activities have much smaller potential emission impacts, even though the impacts of some specific pollutants, such as carbon monoxide (11^{th} emission potential), metals (air) and TSS should not be ignored.

A second group of estimates focused on the total emissions associated with the expected expansion of the sector, as suggested by Kupfer *et alli* (2001). The objective of that study was to estimate the overall effects of the expected expansion in the demand for investments in the O&G sector.

For the total level of investment, two scenarios were elaborated according to different hypothesis about the origin of capital goods :

- Default Scenario: there would be no change in the proportion of domestic capital goods/total capital goods (as observed in 1996). This would represent a total increase in the demand of domestic capital goods of US$ 3,7 billions, at 1996 prices.
- Maximum Investment Scenario: domestic suppliers would attend all the expansion in the demand for capital goods. This is a limit scenario, showing what would be the maximum increase in the demand for domestic investment goods: US$ 5 billions, at 1996 prices.

The tables below present the estimates of the direct and indirect emission impacts caused by the expected expansion in investment:[20]

[20] The expansion of emissions caused by the 5% increase in O&G production would increase the emission of pollutants at the same proportion (scale effect).

Table 37. Estimated increase in emissions in the Default Scenario

Parameter	Emissions caused by the expansion in investments (direct impact)	Emissions caused by the expansion of intermediate consumption (indirect impact)	Total increase in emissions
Water			
BOD	125,9	8,4	134,3
TSS	1236,2	60,2	1296,4
Metals (water)	50,8	1,3	52,1
Air			
SO_2	16567,0	649,6	17216,6
NO_2	13479,1	530,8	14009,9
CO	111536,3	3853,3	115389,6
COV	97170,3	3310,7	100481,0
Fine particulates	97021,7	2405,8	99427,5
Particulates total	176735,4	4269,9	181005,3
Metals (air)	3386,5	102,0	3488,5
Land			
Metals (land)	5011,6	135,2	5146,8

Source: own elaboration, using IBGE data and IPPS coefficients

Table 38. Estimated increase in emissions in the Maximum Investment Scenario

Parameter	Emissions caused by the expansion in investments (direct impact)	Emissions caused by the expansion of intermediate consumption (indirect impact)	Total increase in emissions
Water			
BOD	236,3	8,4	244,7
TSS	2.591,8	60,2	2652,0
Metals (water)	83,7	1,3	85,0
Air			
SO_2	37.275,3	649,6	37924,9
NO_2	27.812,5	530,8	28343,3
CO	229.553,7	3.853,3	233407,0
COV	188.843,9	3.310,7	192154,5
Fine particulates	162.771,7	2.405,8	165177,5
Particulates total	294.776,9	4.269,9	299046,8
Metals (air)	5.687,7	102,0	5789,7
Land			
Metals (land)	8.698,1	135,2	8833,3

Source: own elaboration, using IBGE data and IPPS coefficients

The results above show that the pollution consequences of a new investment cycle would be very heterogeneous. Air pollution is the area that might be the most affected if such a boom of investments is carried out in order to expand the O&G

extraction capacity in Brazil. The parameters with higher growth rates would be metals (air), fine and total particulate matter. Other parameters, such as VOC, metals (water and land) and CO that would have smaller growth rates but still relevant impacts. The remaining parameters (BOD, TSS, SO_2 and NO_2) would have very small impacts.

The low impact expected in water pollution is related to the fact that the IPPS does not provide emission coefficients for natural resource extraction. Moreover, accidental spills are not considered, thus underestimating the degradation of water resources.

Note also that the estimates above are very sensitive to the hypothesis choice. If all the expansion in investment is composed of domestic goods, this would almost double the level of emissions estimated in the default scenario.

5.4.3 Conclusion

The expansion in exploration, exploitation and processing activities in Brazil will continue in the country's effort to achieve self-sufficiency in oil and natural gas. There are important macroeconomic benefits from this, but there are environmental costs too.

One possible way to deal with this is through the elaboration of scenarios. The study of Kupfer *et alli* (2001) considered the enhanced economic activities, created by the investment projects and the increasing level of production and their impacts on the overall economic activity, using the 1996 Brazilian input-output table. When fix emission coefficients were applied to the expected growth in production for each economic sector, it was possible to estimate the potential expansion in the emission of pollutants.

The results of this exercise show that the environmental effects are not homogeneous. The most important potential impacts of the expansion of O&G activities are concentrated in air pollutants (fine and total particulate matter, metals, VOC and CO). Discharges of heavy metals in water and soil also deserve attention. This information may help the design of corrective policies aiming at the minimisation of the environmental externalities generated in the process.

5.5 Future trends for environmental regulation

There is an undergoing process of modification in the environmental regulatory framework in Brazil and in the rest of the world. Environmental agencies have more power than in the past to enforce the application of command-and-control instruments. In Brazil, this is clearly the case of the Environmental Crimes Law (1997) that has increased considerably the penalties for those who do not obey the environmental standards and rules.

On the other hand, there is an increasing role to be played by economic instruments. In the international agenda, the creation of carbon markets shows the changing mentality concerning the best strategy to control pollution and the use of natural resources. Domestically, the new framework regulating water resources has been the leader in the adoption of the polluter-pays principle. However, there is no reason to believe that will be a homogeneous application of different - and sometimes contradictory - instruments for every specific sector.

In the case of the O&G sector, there is a deep contrast between the different ways the environmental regulation will develop. In the upstream chain, the industry has reached a mature stage in technological terms – there are important innovations, mainly concerning deep-sea production, but they are incremental rather than radical. Efficiency gains are more marginal and R&D costs are very high, with low return per unit of investment but requiring considerable capital investment. Therefore it is more likely that command-and-control approach will dominate this area of activities, with more attention to issues such as decommissioning of platforms, reduction of flare burning and an overall concern of avoiding accidents. Since the economy will remain dependent on hydrocarbons for a long time, there is no point of making very restrictive requirements because there is less potential of win-win solutions.

In other words, the main opportunities for environmental technologies are in the end-of-pipe (avoiding "routine" emissions and accidents, which have caught growing attention by regulators, the media and the public in general, not only for environmental reason but also for security issues) and the optimisation of production and distribution processes.

On the other hand, it is quite likely that in the near future the importance of natural gas will increase in comparison to oil: once an almost useless subproduct, natural gas has been regarded as an environmentally better option, and this is already affecting the competitiveness within the sector.

The upper in the energy chain (towards end uses) the higher are the possibilities of new technologies becoming environmental innovations of the “win-win” type. These are more dynamic industries, with huge potential for improvements. Therefore, economic instruments have much more potential, as already demonstrated by the carbon markets that are being established.

The issue of global warming will have a decisive impact on this part of the chain. The Intergovernmental Panel on Climate Change (IPCC) consider that there are only two scenarios that effectively lead to emission stabilisation, and only one of them allows world GDP growth. But this will depend on a move towards natural gas and renewables, and this must be the areas that environmental regulation must put more pressure (since there is more room to manoeuvre by the companies).

The major oil companies already know that improving access to diminishing reserves of hydrocarbons will be a major factor to survive, and reducing their dependence on this kind of energy sources may represent a major competitive advantage. This is not only a consequence of growing environmental concern: political issues will play increasing role. There is a continuous struggle for the access of reserves in the Middle East, and because of the instability of the region, “energy security” is already a growing concern for developed countries (which have less and less control of energy sources – increasing dependence on external sources of energy).

Another important change is the fact that every major oil company is trying to present itself as environmentally concerned. Almost all of them are reacting positively to the global regulatory framework proposed by the Kyoto Protocol and other institutional changes around the Climate Change Convention. But the competitive impacts of changes in the environmental regulation will be different according to the sector:

- Upstream: because of the limitations of radical changes, things will be a bit like business as usual, with gradual tightening on discharge and accidents liability.
- Renewable energies: most companies are interested in renewable sources of energy. This can be understood as a “green hedge” that keep the renewable option opened for them. Investing in alternative technologies now allow these companies to start the “learning curve” earlier, so if they have to move towards new energy paradigms the learning and adaptation costs will be reduced.

There are many examples of the involvement of oil companies in non-conventional sources of energy:

- Exxon/Mobil is investing on hydrogen fuel cells
- TotalFin/Elf: solar, fuel cells and decentralises hydrogen, biodiesel and wind
- Chevron/Texaco: controls 20% of ECD (energy conversion devices); coal gaseification technology to produce hydrogen
- Shell: solar, wind, coal gaseification technology to produce hydrogen
- BP: investments in solar and wind energy, internal accounting system for carbon flows

The pace of the move towards renewables is probably slower than most NGOs would like, but they are aware that the energy companies clearly indicate that they are trying to reduce their dependence on fossil fuels. However, it is also clear that where successful experiences of large-scale adoption of renewables can be found, there was an important role by government incentives.

This means that the environmental regulation needs to combine sensible concerns on conventional energy sources – protect access to existing hydrocarbon sources in order to develop/exploit them with rationality and minimum environmental damage - but also to keep incentives for renewables. Note that this remains a field open to every country, including developing countries, because they do not require extremely sophisticated resources, are not capital intensive and high returns potential per unit of investment (compared to technology in upstream, for example, deep sea oil extraction which is very costly and returns relatively small per unit of investment).

There is a general feeling that something has to be done – to become less intensive in carbon emissions, but there will be a learning period in which many mistakes (and costs) will happen. This is also valid for the regulatory framework, and it would be a great surprise if an extraordinarily new system of global control of the economy, as proposed by the Climate Change Convention, becomes successful in its first try. In that sense, the Kyoto Protocol and other initiatives must be seen as step forwards, but not the definitive framework in order to obtain energy in a sustainable way.

6. Conclusions and policy recommendations

The debate about environmental regulation and competitiveness cannot be summarised by simplistic positions such as pro-industry policies are good (or bad) to the environment. The links between competitiveness and the environment are complex, and there are empirically sound arguments for both positions.

It was shown that the production chain associated with Brazilian industrial exports is more emission intensive than the production chains oriented towards domestic markets. This result is, thus, compatible with the hypothesis that developing countries tend to concentrate “dirty” industries that become less competitive in developed countries because of tighter environmental controls.

This process was, nevertheless, counterbalanced by the emissions “savings” created by the fast expansion of imports in the 1990s. Because they are produced abroad, there is the avoidance of emissions associated with the import goods. Note, however, that this counterbalancing effect was much attenuated by the composition of the import goods basket, compared to the exports: the growth in industrial imports was concentrated in relatively clean activities, particularly those with higher intensity in technology (electronics, for example), while the structure of industrial exports remained associated with more emission intensive sectors. Therefore, the overall reduction in the (potential) emission of pollutants in the Brazilian industry caused by imports growth was smaller than it could have been if these imports were concentrated in “dirtier” activities (intermediate goods, for example).

Another important result was that the direct costs of introducing environmental control strategies are relatively low, considering the industry as a whole. The comparative advantage of being “dirty” are not as high as argued by those against more effective environmental controls. But the impacts of introducing pollution abatement measures may be very different in terms of sectors and destination markets.

It is also important to refer to the role of innovations, which systematically changes the effective relationship between production and environmental control costs. The static nature of input-output exercises does not allow capturing the so-called technological effect, which is essentially dynamic and very difficult to measure and model. It was shown in that firms with international insertion tend to be more concerned with environmental issues and to invest the most in “cleaning” their production processes. Export-oriented and/or foreign capital companies tend to consider the competitive advantages of environmental innovations more seriously than inwards-oriented and/or domestic capital firms do. This is associated with higher environmental standards and pressures in international markets, thus being compatible with the hypothesis that the trade and capital openness process tend to encourage the adoption of environmentally sound practices and products.

These results have important implications for policy making. First of all, it is clear that the relatively high concentration of Brazilian industrial exports in pollution-intensive activities makes these exports very sensitive to the issue of environmental barriers to trade. If there is a change in the institutional framework regulating international trade towards the acceptance of environmental criteria for import control, as advocated by many environmentalist organisations in developed countries, there could be important losses to Brazilian industrial exports. There are two possible strategies to deal with this problem:

a) to adopt an aggressive position against the proposed changes in regulations, maintaining the *status quo* of none/very restricted environmental barriers in the international trade agreements; and/or

b) to enhance the environmental performance of Brazilian industries, either improving local emission standards or changing the composition of industrial exports, becoming less dependent on exports associated with “dirty” production chains.

Even though these strategies are not contradictory, they reflect different perspectives. The (a) option reflects a view that the claims for environmental restrictions in trade (and capital) flows are a short-term pressure that will not be approved in the future. However, one possible problem that may emerge in the forthcoming years is that, with the deepening of regional trade agreements such as Mercosul and possibly the American Free Trade Agreement, Brazilian producers could face competition from the exports from neighbour countries which are subject to much less environmental controls – bear in mind that Brazil is a leader in Latin America in terms of environmental controls. This would be a reversal of the present situation, and in that case the Brazilian producers could be the losers if no standardisation of environmental controls are adopted.

Therefore, the second strategy seems to be a better way to deal with the problem in the long term. There is a smooth but consistent change in the perception of Brazilian policy makers towards the adoption of economic instruments in environmental management, based on the user/polluter-pays principle, and as a consequence some sectors may present short-term losses in their competitiveness. But the good news the results above show are that this overall cost increase may be considerably less than usually thought (with the exception of some specific sectors, that could receive special compensation policies during the transition to cleaner production), and that many firms are already searching voluntarily for better environmental procedures. This is another important feature of international trade that counterbalances the original problem of specialisation in emission intensive activities: the pressures of consumers in developed countries are "reaching their target", in the sense that export-oriented and/or foreign-owned firms tend to see the potential gains from adopting environmental innovations in a different way than firms that are not exposed to these pressures.

However, this transition towards a more environmentally sound economy cannot rely on a *laissez-faire* belief that the simple exposition of Brazilian firms to the market will move towards the desired situation. One important step is the already referred push for economic instruments for environmental management, allowing flexible but efficient measures to improve environmental standards. This must be combined with industrial policies aiming the spread of win-win environmental innovations (energy and other inputs savings; better access to markets, particularly in developed countries; higher quality and efficiency standards associated with changes in processes associated with environmentally-friendly measures; etc.). Some examples of these policies are:

- support for the technological capacitation of firms in environmentally related technologies;
- better dissemination of new technologies in the productive sector;
- improvement of educational and technical skills of the labour force;
- improvement in the quantity and quality of research centres, bringing them closer to the productive sector interests;
- specific programs aiming at the reduction of regional differences in environmental performance;
- incentives to certification programs, including through the process of public procurement; and
- improvement of the domestic consumer's perception of the benefits of environmentally sound products and processes, creating a domestic market for "green" products.

Finally, it must be highlighted that the results presented in this report have important limitations concerning the methodology and hypotheses used, and that data quality is far from desirable. The improvement of data generation and production of environmental indicators are an important need to improve our understanding about the relationship between trade and competitiveness issues and the environment. Therefore, another policy recommendation is the implementation of an effective system of environmental information connected to the already existing economic indicators.

Appendix. Evolutionary economics: an alternative approach

Carlos Eduardo F. Young & Maria Cecília J. Lustosa[21]

The debate on economic growth has always been intense in the economic literature. A new dimension of this debate was introduced in the late 1960s, with the question of whether to accelerate or not economic growth given the rising pressure on natural resources. Considering technology as static, the faster the economic growth, the higher would be the deterioration and exhaustion of the Earth's resources. Only after the oil crisis it became more widely accepted that technological patterns would necessarily have to be changed to deal with environmental problems.

The conventional approach to the problem is based on the standard neoclassical microeconomic foundations, and perceive the improvement of environmental conditions as a cost for producers (current and capital costs for "cleaning" the process, or levies and penalties, in the case of non-compliance), reducing the firm's competitiveness. The social planner has to face the trade off between economic production and consumption, which increases social welfare, and the negative externalities, that reduce welfare. Even though the different models vary according to technicalities (such as whether the pollution is considered as a flow or a stock), the optimal solution always gravitate around an equilibrium between the marginal benefit of increasing production and consumption and the marginal cost caused by the externality.

The main policy principle is to "internalise the externality", under the polluter-pays principle. In order to apply these concepts in policymaking, there was a huge increase in the last two decades of valuation exercises that estimate the social value of the externalities, and the discipline "natural resource and environmental economics" has become a frequent inhabitant of the undergraduate and graduate programmes of economics.

However, there is an increasing uneasy with this traditional approach to the problem. Heterodox economists and social scientists have been searching for alternative ways to face the problem.[22] They tend to refuse the idea that economy and the environment are necessarily in opposite fields, and their question is no more whether to have economic growth or not, but *which kind* of economic growth.

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[21] This appendix is heavily based on previous papers elaborated by the Reserach Group on Environemntal Economics and Sustainable Development (GEMA-IE/UFRJ). See www.ie.ufrj.br/gema.

One school of thought that has been more involved with the environmental debate is the so-called evolutionary economics. Its main fundament is the rejection of the neoclassical treatment of “production function” and technology.[23] Rejecting the idea of “technical neutrality”, they consider that the dominant technologies resulted in unprecedented levels of pressure on the environment, and technological changes are the key to revert the process. Therefore, new dimensions have to be included in the debate: how technical progress is generated and spread out in the production and consumption chains.

One basic assumption of the evolutionary approach is to consider that firms react differently from the same stimulus – in contrast to the neoclassical approach, that is based on a standard “representative” firm. The firms/industrial sectors are responsible for pollution or other externalities because of the adopted technology (not only the production technique but also the organisation of the productive process, the environmental performance of the final product and its disposal, etc.). Hence, the firm/sector capacity to generate and adopt *environmental-friendly technologies* is determinant for a better environmental performance.

This is only possible if one considers that the innovative capacity of the firm depends on its efforts to innovate or to imitate innovations developed by others. Neoclassical microeconomic models are not able to capture the different answers provided by each firm to deal with this problem because of the basic assumption of standardised behaviour. Therefore, it is necessary a new dynamic approach, based on the possibility of “cohabitation” of different technological trajectories.

From a certain moment, the existing technologies may no more satisfy the firm, and many problems can only be solved by innovations. However, the results of these innovations cannot be fully anticipated and, in many cases, incremental innovations are still required, showing the inevitable uncertainty of the process. According to the their better or worse capacity of adapting to the different – and previously unknown – circumstances, the firms will have their competitive positions altered. Hence, it is not necessarily true that the competitiveness of a certain firm will be damaged after the introduction of environmental controls: it will depend on how this firm will perform relatively to the others.

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[22] The International Society for Ecological Economics and its academic journal, *Ecological Economics*, are particularly related to alternative economic approaches to the environemnt.

[23] See Nelson & Winter (1982) for the foundations of this school of though, which is heavily influenced by the work of Joseph Schumpeter

For example, if an innovation is successfully introduced as an answer to a more rigid emission limit (such as a new production process that reduces the consumption of fossil fuels and, therefore, the level of air emissions), the firm may become more competitive because of the environmental policy. There is no general loss of competitiveness, as preached by standard microeconomics, but a rearrangement of the relative competitive positions of firms.

Most importantly, the way firms will react to the policy prescriptions are dependent on the specific circumstances in which they are involved with. Depending on the context, the same kind of policy may lead to a positive answer, such as the adoption of environmental innovations in order to cope with the new restriction, or to a negative response, including corruption or migration towards a region where the restrictions are more lax. From the policymaking perspective, the question is: what forces allow the firm to answer positively to environmental restrictions, through the generation and adoption of innovations.

Lustosa (2002) group these factors as internal and external. Internal factors to the firm include its specific competencies to solve problems, its capacity to absorb and access innovations developed by other firms. Among the external factors there are the current technological paradigm and the institutional framework that supports the innovation process, usually called “national system of innovation” (NSI).

The capacity to solve problems, the first of the internal factors, is accumulated over time. The skills and knowledge owned by the firm, acquired by experience, determine its capacity to create or absorb knowledge, depending on investments in research and development (R&D), individual knowledge of the employees, size and nature of the company (public, private, transnational, etc.), activity sector and degree of specialisation.

The second internal factor is directly related to the first one. The capacity to absorb, according to Cohen & Levinthal (1990), is defined as the skills of the firm to recognise the value of new information, to assimilate and apply it to commercial uses, being crucial its capacity to innovate. These skills to evaluate and use the external knowledge is a function of the level of previous knowledge, since the pre-existence of a common language and other basic patterns between the firm and the external knowledge makes easier the use of the information in a productive way. Thus, the capacity to absorb is a co-product of R&D and the tacit knowledge acquired via production. In that sense, training activities are another way to invest in the capacity to absorb and in R&D, even if no immediate results are obtained. On the other hand, this investment to increase the capacity to absorb is expensive and can be considered as a *sunk-cost*.[24]

The access to innovations developed by others is not free and, in general, presents high costs. Innovations cannot be easily bought as an ordinary commodity, given the lack of information of the potential users, the strategy of the innovator to avoid competitors hiding the innovation, protection by patents and other forms of intellectual rights, and the costs of maintaining the firm with a high capacity to absorb. In other words, the capacity of the firm to innovate is limited by the high costs of internal R&D or to acquire technology from others, and depends on the endogenously accumulated capacities in the technical/productive fields.

The current technological paradigm, the first of the external factors, constrains the capacity to innovate because it defines the scientific pattern in which innovations must be circumscribed. Changes in this paradigm may induce the firm the become more or less innovative, depending on its internal factors.

The NSI, the second external factor, constitutes the organisational system responsible for the development of science and technology (S&T) inside a nation. It is a complex institutional arrangement involving the R&D laboratories of the firms, the research institutes and universities, the funding agencies, the educational institutions, the legal institutions (regulating the competence conditions, intellectual property rights, etc.), the selection mechanisms (the market and other regulatory institutions) and the relationship with other countries. The NSI must be considered according to its three dimensions: the learning capacity, the institutions, and the net of interactions between them. Therefore, an efficient NSI is a powerful incentive for the firms to become innovators.

The macroeconomic context is another external factor interfering in the process. Firms have great difficulty to make risky decisions under great uncertainty, paralysing the innovation process even if they are able to innovate. Symmetrically, macroeconomic stability generates confidence, encouraging the innovation decision.

The degree of competition in which the firm is inserted is crucial in the decision of creating or adopting innovations. For the evolutionary school, competition is the engine of innovation. In competitive markets, the innovation becomes the differentiation factor between the firms and the competitors, also being the only way

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[24] *Sunk-costs* cannot be recovered if the firm leaves the market. In general, they represent the specific

to survive in the market. In this perspective, the firm has only two options: to innovate or to die.

Finally, the regulatory framework also affects the innovation process. Some sectors require more regulation according to the kind of activity and market structure in which they are surrounded. For instance, the economic activities with higher environmental impacts are subject to specific controls, which can turn out to be incentives to innovations, depending on the objectives and instruments of the environmental policy.

Environmental problems must be studied in a dynamic perspective, too. Historically, the nature of these problems has changed with time. The question of accumulation and irreversibility of environmental problems is equally relevant. In the first case, new problems appear as the degradation of the environment increases. The accumulation of sulphur dioxide in the atmosphere, for example, generates acid rain, creating the need for innovations to deal with the problem. In terms of irreversibility, innovations are necessary to recompose, at least partially, the environment. Deforestation leads not only to biodiversity losses, but also to erosion and degradation of soils. Recuperation and afforestation technologies become necessary to recover some of the natural properties of the ecosystems, in many cases requiring a considerable number of incremental innovations. These innovations may or may not bring another environmental problems, as in the case of the replacement of horses by cars.

Therefore, either because of natural mutation or anthropic interference, the environment is in constant evolution and, as in the analysis of innovation process, it can only be adequately studied under an evolutionary perspective. This reinforces that the analysis of environmental innovations must be undertaken using the evolutionary economic theory, emphasising the dynamic vision of the economic processes.

The firm's capacity to create or adopt environmental innovations is decisive for improvements in local and global conditions – adequately managing natural resources, controlling pollution, etc. Environmental improvements may be translated as less use of natural resources and energy per unity of output (better efficiency in input use), less pollution and recovery of degraded ecosystems, expanding the economic possibilities inside the environmental limits. Environmental innovations are

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assets of the firm (Schmalensee, 1990).

fundamental to harmonise preservation and economic growth, allowing a better access to consumption for a greater number of people.

The solutions for pollution problems can be either *end-of-pipe* (EOP) or *pollution prevention* (PP). In the first case (EOP), also called end of line treatment, toxic substances are treated before their emission to the environment – contamination control – and also includes the cleaning up of degraded ecosystems. The second case (PP), also associated with the concept of *eco-efficiency*, includes the adoption cleaner technologies, improvements in the efficiency of production through innovative management, less residuals generation and recycling of subproducts (López, 1996). The PP approach foresees changes in adopted technologies and management practices, while the EOP approach is based in already existing technologies, which can be better considered as palliatives than definitive solutions that effectively reduce emissions and residuals (as in the case of PP). For this reason, the definition of innovations is restricted to those associated to the PP approach.

Nevertheless, as pointed out by López (1996), the limits between EOP and PP solutions are not clear in practical terms. An EOP treatment may recover substances that can be recycled. Furthermore, an eco-efficient solution does not eliminate completely the harms to the environment, thus requiring complimentary EOP treatment. In other cases, instead of being complimentary, it is possible that these two kinds of treatment lead to conflicts in short and long term objectives (Foray and Grübler, 1996). Eco-efficiency (PP) is a long term objective and requires policies that encourage the generation and adoption of environmental innovations. EOP solutions aim at emissions control in the short run and their access is easier, because they can be adapted to existing technologies without radical changes in production and organisation of the firm. Hence, environmental policies that target pollution reduction in the short run through EOP solutions may discourage the adoption of more radical changes.

Foray and Grübler (1996) highlight three relevant questions in the relationship between technology and the environment. The first one refers to the uncertainty, unfamiliarity and disperse knowledge in the generation and distribution of technologies, including those related to the environment. New technologies are associated with uncertainties concerning their properties and current and future impacts. These impacts may be associated to the uses of the technologies and the magnitude of their diffusion and potential cumulative impacts. The unfamiliarity is connected to restrictions in the access to new knowledge because "*there is simply a* *difference between knowledge that may exist somewhere and knowledge that is available in the right form, at the right time, to the right people*" (Foray and Grübler, 1996, p.8). Moreover, knowledge concerning the environment is disperse (with a potential role for the new information technologies to minimise these problems).

The second question refers to the tensions between inertia and stability of existing technologies and the factors inducing to technological change, including environmental conservation. As already mentioned, technologies are the result of previously defined trajectories, creating a *lock-in* effect. The generation of eco-efficient technologies becomes a challenge, even though the potentially inductive role of environmental criteria. An important question arises: how to surpass the technological inertia to accelerate the transition towards new technologies and institutional configurations that internalises the question of environmental conservation?

The last question deals with the policy dilemmas concerning environmental questions. The objectives of these policies in the short and long run may be not compatible, as already referred to in the issue of EOP and eco-efficient solutions. Conflicts may also arise between public policies and controls, and the innovation behaviour of the firms. Moreover, the technological diversity required for the different environmental questions is potentially incompatible with the trend for standardisation, in order to reduce costs and generate returns of scale. Finally, there is the dilemma between the need to accelerate the creation and diffusion of environmental technologies and the necessity to minimise the technological irreversibility.

Kemp and Soete (1990) argues that the creation and diffusion of environmental technologies differ from the traditional process of technical change, which usually consists in the succession of newer and more efficient production techniques. The authors point out the essential factors to the development and diffusion of environmental technologies in different economic sectors. These factors can be separated in terms of the supply and demand of environmental technologies.

Technological opportunities are a fundamental supply factor. These opportunities differ in sector terms, and depend on the available equipment and the existing scientific and technical knowledge – depending on them, the required solution can be easily achieved with existing technologies, or become a difficult question without answer even in the near future. Another factor affecting the supply of environmental technologies refers to the conditions of appropriability. The social interest in the fast diffusion of these technologies will justify the pressure to reduce the time of appropriability but, with the growing expectation of more rigid restrictions, the control of cleaner technologies may become an important competition factor. Finally, the instability of the demand for these technologies impedes the full development of the industrial sector dedicated to them.

Among the factors affecting the demand for environmental technologies, Kemp and Soete (1990) firstly consider the problems related to knowledge and information. These include both the technical competence to adapt new technologies and the knowledge over which techniques are available, how to access and how to fund them. Insecurity and uncertainty in the adoption of new technologies, given the risks involved, are other factors affecting demand. New technologies require changes in routines and training, again with uncertain results. In addition, there is the risk of the technology becoming prematurely obsolete because of changes in environmental standards, and the evaluation of these risks vary widely, among firms and sectors.

The relationship between producers/users also affects the demand for environmental technologies. Given the diversity of environmental problems, it is difficult to imagine a producer of clean technologies for all sectors. Moreover, the producer of clean technologies will rarely be the most important supplier of technologies to the companies. The last factor pointed out refers to the distinction between innovations in products and processes, which differ considerably. Product innovations must obey to the demand of consumers for what they consider as “ecologically correct” products, depending on the importance they attribute to each of the components of the environment, and their willingness to pay for this kind of product. Process innovations are related to the objectives and values of the firm, with predominance of cost-efficiency factors.

The market structure also influences the diffusion of environmental technologies. In general terms (despite of very important exceptions), small and medium companies have less perception of environmental problems and information on environmental technologies. It is expected, thus, that these firms are less inclined to be innovators. Other decisive components are the degree of competition between firms and their financial situation. Markets where competition is based on lower prices, where profit margins are low, or with low degree of competition (monopolies or protected markets) tend to negatively influence the decision to adopt and develop environmental technologies.

In summary, dealing with environmental innovations using the evolutionary approach, it is possible to formulate the following hypotheses for the different behaviour presented by the firms concerning environmental innovations:

1. According to the internal factors enabling firms to generate and adopt innovations, the innovative firms are those with higher R&D investment, higher level of qualified personnel, higher size and level of information. In the specific case of environmental firms, one must add firms with global interests (in the case of developing countries), better financial situation, and those that include environmental concerns in their objective and values.
2. However, since the factors of efficiency and costs dominate the objectives of the firm, the adoption of environmentally friendly production techniques is not a priority, despite of the growing conscience and social pressure (Kemp e Soete, 1990). Therefore, voluntary attitudes to reduce pollution will be relatively limited, and specific controls and policies are necessary for a more widespread adoption of cleaner technologies, particularly to force big polluters to reduce their level of environmental harm.
3. Firms with high level of competitiveness are more inclined to answer positively to environmental questions, since environmental variables may become another factor to reinforce their competitive position.
4. External factors influence the decision to create and adopt environmental innovations. The incentives to innovation are positively related to the degree of institutionalisation of environmental issues, the macroeconomic stability, the development of the NSI, and the competition in the markets where firms are inserted in.

Competitiveness and clean technologies

The main reason for the increasing popularity among academics of the concept of "clean technologies" is related to the possibility of reverting a cost into a benefit: what would be previously seen as a problem (additional expenditures to control emissions or to pay for compensations, if the emissions reduction is not economically or technically feasible) becomes an advantage (better output/input ratio). Because of this double dividend, in economic and environmental grounds, it results in a win-win situation that simultaneously satisfies businessmen, environmentalists and policy makers. But a question always remains if the clean technologies are the best for both business and society, why they are not always adopted in large scale? And why there is a need for specific programmes aiming at their diffusion?

There are many different aspects to be considered in this question. First of all, it is essential to contemplate that productive units are extremely heterogeneous, even more in peripheral countries of late industrialisation. This structural heterogeneity is the consequence of inequalities and disequlibria between sectors, which accentuates the differences in technological patterns. This disparity is well perceived in the comparison between some sectors that require a high degree of technological updating (most of durable consumption goods that incorporate microelectronic innovations, for example) and more traditional activities that are much less demanding in terms of technological changes (mostly in the non-durable consumption goods sector). Moreover, within the same industrial sector, firms well advanced in technological terms coexist with companies that are very behind the latest technological patterns. In some cases, this distinction can be perceived between export-oriented firms, that have to follow higher degrees of competition, and the ones oriented towards domestic markets that are less demanding in terms of quality of the goods (cheap price being the most important competitive issue). However, there are also counter examples where the export strategy is related to cheap labour or natural resources endowment, instead of higher quality (mostly in exports of raw materials or some agricultural goods), while import liberalisation resulted in the sophistication of consumer markets even in developing countries (at least, within the upper classes).

Therefore, the opportunities for the diffusion of clean technologies vary widely. Where the technological gap among competing firms is large, there are lots of opportunities for improvements in the production processes of the most downgraded firms. In this case, the role of public policymaking is to facilitate technological transfer in both the diffusion (e.g. improving the knowledge of best practices available) and funding strategies for technological upgrading. Another area that can be exploited is through public procurement policies, in which the set-up of minimum standards for the company to be accepted as a supplier or a concession holder may induce changes within the private sector.

A more complicate situation refers to the cases where win-win solutions are reduced or in industries where capital units are recent, and the adoption of cost-saving clean technologies would require further investments in plants that have not yet been financially depreciated. The situation is even worse when the financial capacity of the companies is very limited, typically in small and medium businesses: even if the best practice is known, scale or capital restrictions impede their adoption, and the only feasible way of enforcing the environmental management is through end-of-pipe solutions that represents higher costs (therefore, reducing their competitiveness).

In other words, it is not possible that the best environmental practice results in cost reduction situations. This limitation is important, but frequently forgotten in over-optimistic assessments about the potential of clean technologies. The policy maker, from both public and private sectors, has to be able to differentiate the win-win situations and the cases in which there are potential threats to the firms' competitiveness.

Chudnovsky *et al.* (1997), in their study about competitiveness and environmental management in the Argentinean industry, provide an interesting analytical framework to distinguish three groups of possibilities:

Table 39. Possibilities of environmental improvements

Clean technologies	Process optimisation	End-of-pipe treatment
Adoption of new production processes that reduce environmental impacts. Development of products or processes with "ecological" characteristics	Optimisation and other strategies to increase the process efficiency with the existing installed capacity. Reuse of inputs, subproducts and residuals; changes in the use of raw materials and other inputs.	Treatment of discharges and residuals, avoiding/reducing their threat to the environment.

Source: Chudnovsky et al. (1997)

The circumstances that lead to the adoption of clean technologies and process optimisation are usually associated to industries that operate in continuous flow, where the reduction of residuals and energy consumption can represent a considerable reduction on costs (less waste = higher profit). A good example of this win-win possibility is the Brazilian sugar and alcohol industry: in the 1970s and 1980s, the discharge of organic-rich liquid effluents (*vinhaça*) resulted in serious contamination of rivers near the plants. However, this residual becoming reused as organic fertiliser, reducing the costs of fertiliser purchase at the same time that reduced considerably water pollution. Another interesting reemployment of residuals in the same sector is use of sugarcane bagasse to generate energy, reducing solid waste at the same time that electricity surplus is now being sold to the main grid companies. Similar examples can be quoted from the pulp and paper industries (for example, energetic use of wood disposals) and refineries (cogeneration, reusing heat to generate electricity).

These industries are used to emphasise technology as a main competition tool, with a “virtuous” cycle between efficiency, innovative capacity and pollution control (Chudnovsky *et al.*, 1997). On the other hand, where the innovative capacity is less developed, the advance of environmental control tends to be more concentrated in end-of-pipe solutions. Because of this, small and medium enterprises may have to face a disadvantage; however, this is not a problem concerning the size of the firm. Even if the company is large, an organisational structure that does not encourage innovation will induce only marginal improvements, such as end-of-pipe treatments that do not affect considerably the production profile. Therefore, these companies will face much more problems to adopt more radical changes than in firms where pre-exists an organised system to adopt innovations.

Many of these transformations are also linked to demand pressures, mostly in developed countries where NGOs, consumer associations and governments are more demanding about the environmental “footprints” of goods and services. The strengthening of environmental control agencies is crucial, especially under the current trend of adopting economic instruments in public environmental policy. The polluter pays principle (PPP) is an important way to enforce changes in a more flexible way, benefiting those who are “cleaner”.

Another important issue concerning environmental policymaking is the harmonisation of environmental standards in the process of economic integration. This is necessary to avoid “pollution havens” in areas with more lax legislation or poor enforcement, with the risk of creating spurious mechanisms of competitiveness that favour the firms that spend less on pollution control. Therefore, higher involvement of the private sector in environmental management does not mean less public efforts in the same area.

A similar fallacy refers to the liberal-orthodox argument that trade liberalisation is enough to guarantee a “cleaning” of the industry, because it would eliminate the most inefficient producers that are associated with the highest degrees of contamination. According to this view, simply increasing the competition among firms would automatically reduce the levels of industrial pollution. Nevertheless, there is no reason to believe that the market, by itself, will elect the companies are environmentally the most adequate. Moreover, this rationale induces the principle of static comparative advantages, which states that developing countries must specialise in the and exports of goods that are intensive in the cheapest production factors: labour and natural resources simply because they do not present in the short run the same advantages as developed countries to produce more sophisticated goods. In the long run, this dependency on cheap sources of labour and natural resources will lead to their overexploitation, with negative results in both social and environmental grounds, and with modest, if any, economic benefits – no sustainable development can be achieved this way.

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