Determinants of Environmental Performance in the Brazilian Industrial Sector*

Ronaldo Seroa da Motta
Research Institute of Applied Economics (IPEA)
seroa@ipea.gov.br
Rio de Janeiro, Brazil
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This study will analyze the determinants of environmental performance in the Brazilian industrial sector. It uses a database conducted by the Brazilian National Confederation of Industries inquiring about questions on environmental management over 325 medium and large firms referred to the year 1997. We have been able to test three proxies of environmental performance, such as a weighted average number of environmental control practices, environmental investments and operational cost ratios, controlling for actual data on market incentives and enforcement pressures as well as for declared motivations. Our results suggest that the Harrington paradox can be observed in Brazil when a compliance-dependent regime motivates firms to comply with low sanction level. Consistent with results in the main literature, our study confirms that, apart from some expected characteristics of the firm, as size, sector and foreign ties, demands from communities and market incentives are also very influential determinants. Cost savings on inputs and subsidized credit are found equally important. Based on that, we recommend flexible instruments on pollution control that capture the firm's differentials in characteristics and compliance levels as well as dissemination of information on environmental control and related cost saving opportunities.

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Introduction

The benefits of pollution control are usually widespread over the whole society. High transaction costs of assigning and securing property rights over most goods and environmental services make those suffering from harmful effects of pollution unable to seek full compensation against emitters. This is the typical case of a negative externality i.e., third party damages that market is not properly pricing.

If the benefits of pollution control, that is, the damages avoided, are lower than the respective private control costs, emitters will lack incentives to undertake it. So pollution control is a typical case of governmental intervention to correct a market failure. The classic paradigm for environmental policies is then based on the regulator (a principal) controlling private agents through regulation. Non-compliance with norms and rules dictated by the regulators is liable to sanctions.

The seminal work of Becker (1968) on general legal compliance stated that profit maximization would make agents equalize non-compliance and compliance costs at the margin. Compliance costs require that firms incur in expenditures to adjust themselves to the norms and rules set in the regulation.

Non-compliance costs are sanctions applied to the firm that has not made the required adjustment and depends on the level of the sanction weighted by the probability of being caught, that is, the expected sanction value. While sanction values are usually known (penalty value, closure costs, etc), the probability of being caught is not directly observed by firms. Regulators may play different strategies from low sanction values with high monitoring level to high penalties with low inspection rates. Firms will have their own

expectations on the probability of being caught and make compliance decisions against their expected value of non-compliance costs.

This model should also apply to environmental regulation where norms and rules affect almost all production activities. Harrington (1988), however, analyzes the apparent paradox that in the US firms that tend to show high compliance rate despite the fact that the Environmental Protection Agency (EPA) is highly tolerant with non-compliers, and consequently expected sanction values are usually lower than non-compliance costs.

Harrington (1988) solves this paradox with a repeated enforcement/compliance game where EPA utilizes a state-dependent enforcement regime in which firms are classified in two groups according to their violation records in the last inspection period. In Group 1 are those not in violations in the last period and in Group 2 are those found in non-compliance. When firms are in Group 1, violations are monitored and sanctioned with much lower penalties than those in Group 2. So penalty in Group 2 is the expected high penalty plus the present value of returning to Group 1 in terms of laxer treatment when compared to Group 1? Harrington (1988) showed that in equilibrium, high compliance is compatible with low penalty and inspection rates, since the state-dependent regime creates inspection and penalty differentials working as incentives to firms in making efforts to be part of the good compliers in Group 1.

Deily and Gray (1991) focus on the role of the regulators so as to maximize net political support, as suggested by Stigler (1971), using pollution control data on the US steel sector in the period 1977-86 of declining sectoral activity. They found that in high-polluted and concentrated areas, regulators may gain political support from more enforcement, whereas firms that are major employers and likely to close are subject to less enforcement.

Following the principal-agent problem issues, Garvie and Keeler (1994), applying a Stackelberg sub-game with complete information, analyze how compliance is affected by the way regulators balance expenses on monitoring and actions to levy penalties and also by public consensus on the desirability for better environmental conditions. They also analyze private information problems when regulation is discretionary to equalize compliance costs across firms.

Literature also analyses how firms comply when they face public scrutiny. Wheeler and Afsah (1996) study how a 1995 program on information release about firms' environmental performance has largely contributed to high compliance rates in Indonesia where there is a weak formal enforcement regime.

However, Konar and Cohen (1997), applying an econometric model, undertake a similar analysis for the Toxic Release Inventory (TRI) , started in 1988 in the US, in which they found that negative media attention to firms' emission levels, after controlling for the firms' characteristics, particularly size, has not affected decisions on environmental compliance. That is, ability to comply dominates market incentives. Hamilton (1995), instead, found correlation between intense media exposure of high emitters and declining stock prices, analyzing the same program although controlling for exposure intensity.

Magat and Viscusi (1990) and Laplante and Rilstone (1996) deal with the endogeneity of regulation enforcement in compliance level decisions with two-stage regression. Theoretical models have also shown that market incentives are important and Reinhardt (1999) identifies how the managerial skills of firms and its rank in the market can be both influencing compliance.

Quantitative studies in developing countries have mostly addressed the effects of informal regulation, that is, how communities and NGOs may affect the environmental

performance of firms. The first approach was to regard informal procedures as a complement of weak formal enforcement. Local community members can act negatively against bad compliers in different forms, from political sanctions to boycotts. Pargal and Wheeler (1996) test this hypothesis for Indonesia using data on industrial wastewater. Apart from the importance of firms' characteristics, they found that there is high elasticity between emission and community income and education levels. Hettige, Hug and Wheeler (1996) review studies on determinants of pollution abatement in South and Southeast Asia and found some similarities with the results in Indonesia regarding informal regulation. Panayotou, Schatzki and Limvorapitak (1997) analyzed environmental investments in Thailand and found that formal and informal pressures were influential on firms' decisions and Blackman and Bannister (1998) did the same for propane substitution in Mexico.

Nevertheless, these studies, by using community data and not actual observations on pressure levels, were not able to distinguish community action channeled through regulators, and thereby part of the regulatory procedures, from the one that is directly engaged towards the firms. Recently, Dasgupta, Hettige and Wheeler (2000), based on a detailed field survey, analyzed how abatement control was determined in the Mexican industrial sector. They used indicators of self-evaluated performance with endogeneity for several environmental management variables and found again evidences on firms' characteristics but little on market incentives and none on informal regulation measured from responses of the survey. They suggest that indirect community pressure through regulators can be the case.

Ferraz and Seroa da Motta (2001) applied a model with endogenous non-compliance sanction, determined in two-stage regression, regressed against investment decisions. They relied on a database for the industrial sector of the State of São Paulo, the

most developed region of Brazil. Results confirmed this indirect way with significant coefficients to ecological voting trends, number of NGOs and income levels in the sanction function. They also found evidences on firms' characteristics and market incentives, as, per example, high export sales, affecting environmental investments.

As can be seen from this short summary of literature review, we can assume that the environmental performance of the firms can be affected by their own characteristics (ability aspects), market opportunities (incentive aspects), regulatory procedures (sanction aspects) and community pressure (informal aspects).

3. Pollution Regulation and Enforcement in Brazil

In Brazil not only EPA but also any citizen can act against polluters for non-compliance. Anyone can denounce a polluter to the EPA and/or to the Public Prosecutor Office (MP).

Firms face two types of legal sanctions, namely: (i) administrative fines imposed by state EPAs and (ii) remediation and clean-up legal sanctions imposed by the judiciary. The payment of an EPA fine does not free firms from legal remediation sanctions and criminal charges[1].

Environmental pollution control is decentralized to states[2] but non-compliance sanctions usually conform to the federal law in three levels: serious, mild and light. EPA, however, in extreme cases, can set plant closure. Fine categories are defined in law but their interpretation and pecuniary charges are set by states on range values. Only very recently, states have revised upward these values, because they had been depreciated by inflation in

[1] A new environmental criminal law has been approved in the National Congress last year with very stiff sanctions, including imprisonment. However, its regulation is only due to next year.

the late eighties and early nineties.

Fine application follows some general procedures: (i) warning; (ii) fine setting; (iii) the firm's defense of the fine; (iii) fine analysis; and (iv) fine application. In most states, the fine value is applied by the EPA and its analysis conducted, in severe cases, either by the Secretary of the Environment or by a state council linked to the State Secretariat of the Environment, where non-governmental environmental agencies and civil society (industrial associations, NGOs and academia) also have seats. If the fine is confirmed, firms can only appeal to the judiciary. As can be seen, EPAs spend a great deal of work on sanction setting and analysis, which means that enforcement costs are not negligible.

When firms are caught on non-compliance status, apart from the fine, they are forced to return to compliance. However, agreements are usually set between violator and EPAs and/or judiciary (called "term of behavior adjustment", TAC), which allows firms a grace period to achieve compliance. The contents of TAC often account for economic constraints faced by firms and the need to compromise with regional development goals that the firm's activities may be related to.

Firms undertaking activities with potential environmental impacts are required to have an environmental licensing granted on environmental criteria[3]. This permit to operate an industrial plant has to be obtained prior to operation and periodically renewed (4-5 years) [4], and is issued according to environmental impact assessment reports (EIA-RIMA).

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[2] Problems with transboundary pollution and rivers and ecosystems crossing more than one state are dealt by the engaged states led by the federal EPA.

[3] Of course, political pressure, particularly on the state governor, can force, in some cases, a high degree of relaxation. This is, however, more common on infrastructure projects with diffuse sources of degradation than on located industrial plants with an easily spotted source of emission.

[4] Licensing is granted preliminarily during plant project design phase and later for operation (licensing of operation, LO) which is, in fact, the ultimate licensing status.

Licensing is analyzed by the state EPA but its issuing is often authorized by the Environment State Council. Licensing procedures are supported by a 1981 federal law, regulated in 1986 and revised in 1998. These legal bindings make mandatory Council's decisions on licensing, and are not disputable in judicial litigation, although failure to meet licensing requirements can be deferred with the TAC instrument. Since the installation of a firm is easily spotted, the monitoring of licensing is also easily undertaken. Moreover, licensing is mandatory for several entitlements of governmental incentives (fiscal and credit ones). Consequently, firms have learned that licensing is not easily avoided, and therefore, there is a very low proportion of firms with full non-compliance licensing status.

Public prosecutors do not have a budget for monitoring and their work consists of putting together a case with the collaboration of governmental and non-governmental organizations. Interesting to mention is that in Brazil, mostly due to acute social problems, violators are sometimes forced by judges to pay for social expenditures (from hospital building to food distribution) instead of full remediation or clean-up actions.

Firm's defense cost varies. In the case of sanctions, it can range from just a letter or a simple report contradicting the findings of the reported violations to a dense report with monitoring data. Judicial litigation is costly and often avoided unless in extremes cases of imprisonment and closures (which are also very rare). Although most fines applied are confirmed, firms have the incentive to avoid their payment since enforcement for administrative fines is rather weak.

The EPA fines are collected by the state treasury and usually funded in the EPA's budget. Not only their values are not high enough to motivate the treasury to allocate efforts on collection as well as it does not get a share on the resulting revenue. Nevertheless, fines are eventually paid since they will constitute a liability for firms as governmental debt and

may jeopardize the firm's relationship with other governmental licensing and credit and fiscal benefits. On the other hand, EPAs do not follow-up fine payments that are totally controlled by the state treasury in a very non-systematic manner. On the other hand, judicial payments are relatively easier to enforce, although they may take longer to be set against firm due to judiciary procedures.

Each state is responsible for its own territorial monitoring on industrial sources. Systematic and randomly monitoring is rare. Monitoring is mostly driven by four factors: (i) environmental harm potentiality and past behavior of firms; (ii) follow-up of licensing agreements and TAC; (iii) demand from public prosecutors; and (iv) community complaints on change of media environmental quality. The former two factors are endogenously defined by EPA whereas the latter two are defined outside.

Community denouncement is very common in Brazil and it can usually be made by a phone call. Once the case gets space in the news media, its priority on EPA strategies increases. NGOs are frequently a main source of pressure to denouncement, particularly those that are locally organized.

Since EPA managers can be prosecuted due to mandate failures and they are always facing a great deal of systematic monitoring inefficiency, they tend to give high emphasis to these denouncements. And, in fact, EPA performance is measured by its capability to act promptly against these notorious cases. Also, currently, public prosecutors have been imposing a great monitoring burden on EPA for their own actions.

Few states have implemented self-monitoring practices, although they have failed to implement efficient random field verification on firms under this system. Although there is no specific rule for lower fines for self-reported violations, EPAs tend to apply lower fines for self-reported violations. That is also true for violations by firms that are not in the

self-reporting system, which, by any reason, report their violations (particularly the accident-related ones with "visible" consequences).

Media environmental quality has only recently been expanded. In case of water quality, due to the importance of hydroelectric energy generation in the country, monitoring is systematic in many states for certain basins covering mainly organic matters and suspended solids. Few major cities, with an acute air pollution problem, have systematic air quality monitoring as well as industrial zones have their own monitoring structure. Because of the lack of consistent and systematic media monitoring, public perception (visual changes, smell, fish mortality, human health incidences, and so on) is the major indicator for denouncement and basis for EPA actions.

4. Database Analysis

This section presents details of the survey from which data for our study is based on and presents bivariate analysis of the variables that will be applied in our econometric model.

4.1. The Sample

In 1998 the Brazilian National Confederation of Industries undertook the "Survey on Environmental Management in Brazil" (CNI, 1998). This inquiry, hereafter called CNI survey, was carried out in the period August-September 1998 inquiring the situation of respondents related to year 1997 and for some financial variables to 1996. Its main aim was to generate insights that would allow governmental and development agencies as well as the industries themselves and their institutions to evaluate strategies, policies and instruments to enhance environmental management.

The CNI survey covers the whole country and industrial sectors. Two types of questionnaires were adopted: (i) a broad one applied to medium and large firms (27 questions) and (ii) a simplified one applied to small firms (10 questions).

The simplified version was necessary since small firms do not keep a wide variety of records, apart from the fact that they are responsible for a minor share of the industrial product, and consequently, of the total pollution generated in the sector.

The broad version of the questionnaire covered aspects related to economic and financial profile of the firm, environmental management practices, relationship with regulators and non-compliance sanctions and expectations on major environmental issues and policies. The simplified one addressed only a few economic information and some aspects of environmental practices.

To facilitate the filling out of the questionnaire and achieve a greater rate of responses, all economic and finance questions that could be informed in monetary terms, are indicated by brackets of percentage intervals related to some other variable, which could be one not inquired, such as percentage of total investments. Exceptions are for revenue and number of employees, which are given in continuous form. Since qualitative questions on environmental management are also in indicative form, our analysis will be heavily based on discrete variables. Although this is a drawback usually faced by most field surveys, such restriction reduces the analytical power of our exercises.

Responses in the questionnaire are related to the major production unit within the state where the firm is located. The size cut is the following: small firms: less than 100 employees; medium: between 100 and 499 employees; and large: over 500 employees.

The sample of 1,451 questionnaires was extracted from a population of 85,600 production units and each size cut was also represented by an aggregation of sectors (total

of twenty-three) and regions (total of four). Medium and large firms represent 14% of the number of the respondents. All sample characteristics and representativeness were made out from the database of the Ministry of Labor, which is based on a compulsory annual inquiry related to legal labor norms.

Due to the limitations of the small firm's questionnaire, we will proceed our analysis on the broad version only. Therefore, our study will be directly related to medium and large firms and will be based on an initial sample of 325 firms that was later reduced due to missing values and outliers as will be discussed in the Annex.

4.2. Dependent Variables

As already mentioned, we intend to analyze the factors influencing environmental performance in the Brazilian industrial sector. To carry this on, we need to select an indicator that measures this performance.

The most appropriate indicator for that purpose would measure firms' pollution impacts since performance, in this case, would be the balance between emission and assimilative capacity. A cross analysis of this indicator would give us the relative magnitude of the firm effort in pollution control against the rest of the sector. The measure of such indicators, however, is far from being trivial. Assimilative capacity is very difficult to measure because it varies locally and is pollutant-specific; emission, as well, is not always observed or reported and may take a form of different pollutants.

Not surprisingly, all studies addressing this issue of environmental control determinants have made use of this indicator, and proxies were utilized instead. These proxies could be broadly classified in three categories; namely: (i) total emissions (Pargal and Wheeler, 1996; Pargal, Mani and Hug, 1997, and Konar and Cohen, 1997); (ii)

environmental investments (Panayotou, Schatzki and Limvorapitak, 1997 and Ferraz and Seroa da Motta, 2000); (iii) self-assessed compliance performance (Dasgupta, Hettige and Wheeler, 2000) and (iv) environmental management system (Dasgupta, Hettige and Wheeler, 2000).

In this study, our database allows us to use proxies for environmental management system and investments. We will also analyze environmental operational costs.

Environmental Investments

The environmental investment variable was defined in the CNI survey as any capital expenditure related to pollution control, energy conservation, raw material saving and those related to cleaner processes and environmental certification.

Table 1 – Frequency of Environmental Investment Ratios

Environmental Investment Ratio	*1996 Percentage*	*1997 Percentage*
no investment	21	18
less than 1%	28	23
from 1 to 3%	24	23
from 3 to 5%	10	15
from 5 to 10%	10	13
from 10 to 20%	4	5
over 20%	3	3

The magnitude of the environmental investments was measured as a proportion of the total investments undertaken by the firm in the years 1997 and 1996 according to seven pre-established percentage brackets, namely: zero; between 0 and 1%, between 1 and 3%; between 3 and 5%; between 5 and 10%; between 10 and 20%; and over 20%.

Table 1 above shows the frequency of the ratio responses. From this table we can observe a monotonic decreasing frequency from the second bracket onwards. Note, also, that the great majority of the samples, 79 and 82 %, respectively, in the years 1996 and 1997, are indicating that they have made investments. In our econometric exercise we will convert these seven brackets into seven dummy variables.

Environmental Operational Costs

The third indicator is the environmental operational cost defined in the CNI survey as expenditures that took place in order to operate the above environmental investments, including those related to environmental marketing, monitoring and auditing.

Table 2 - Frequency of Environmental Operational Cost Ratios

Environmental Operational Cost Ratio	Percentage
No costs	29
less than 5%	63
over 5%	8

The magnitude of the environmental costs was also measured in ratios against total operational costs in the year 1997 according to five pre-established percentage brackets, namely: zero; less than 5 %, between 5 and 10%; between 10 and 15%; and over 15%.

Nevertheless, these brackets were overestimated and no firm acknowledged a ratio over 10%, as shown in frequencies of Table 2. The frequency of 71% for positive ratios is compatible with the positive ratio of environmental investments in 1996. We converted the three ratios in Table 2 into three dummy variables in our econometric models.

Environmental Control Practices

The CNI survey inquires firms their motivations for adopting the environmental control practices that are already in place and properly functioning. Based on this information we construct an index representing an average number of practices adopted by each firm, as described in Table 3.

Table 3 - Frequency of Adopted Environmental Control Practices

Environmental Control Practices	***Percentage***
Reduction in the use of raw material	33
Reduction in the use of energy	35
Reduction in the use of water	36
Change in packing	13
Liquid effluent control	50
Air emission control	27
Noise and vibration control	43
Disposition of solid waste	51
Recycling of solid waste	61
Substitution of raw material	21
Training of employees	31
Requirements of suppliers	20
Others	4
No adoption of environmental management practices	4

The procedure is a weighted sum of adopted practices where weights are given by the sample frequency of each practice shown in Table 3. As can be seen in this table, the highest frequencies are those related to recycling and disposition of solid wastes followed by noise and liquid effluent control. This index assumes that the most adopted practices are either the cheapest or the most stringent ones and that performance is improved when

additional practices are added. Note that this constructed variable is continuous and proxies a stock indicator capturing control efforts through time. Summary of the estimated index is presented in Table 4.

Table 4 - Statistics of the Environmental Practice Index

Variable	*Obs*	*Mean*	*Std. Dev.*	*Min*	*Max*
Environmental Practice Index	310	168.76	95.42	4	425

Note that the deviation from the mean value is not great but the index distribution is fairly skewed towards the right. In our econometric models we use a log form of the variable to decrease the importance of the highest values.

The expected biases of this index are that it does not capture specific characteristics of the firm's activity and regulation pressure. Apart from being the same biases when the monetary dimension of capital stock or investment is used, these biases are just the controls that we want to apply in our econometric models.

4.3. Independent Variables

As already discussed, we want to identify factors influencing environmental performance, such as, firm's characteristics, market opportunities and compliance pressures. Next, we analyze how the CNI survey offers us proxies for these factors.

This analysis will be carried out comparing our indicators against the selected variables using frequency of firms according to the percentage brackets of environmental investments and costs and the distribution around the mean for the environmental practice

4.3.1. Characteristics of the Firm

These characteristics represent the ability or capacity of the firm to perform environmental control considering its managerial skills and the technological restrictions of its activity. The CNI survey allows us to select four types of characteristics, namely: size, origin of capital, management unit and sector.

Size: The size of the firm can be measured either by the number of employees or revenue. As previously mentioned, the former was used to design the sample. We may expect that the larger the firm the higher its ability to perform. Moreover, larger firms tend to be more easily spotted by the media, regulators and communities besides being more sensitive to the reputation of its public image.

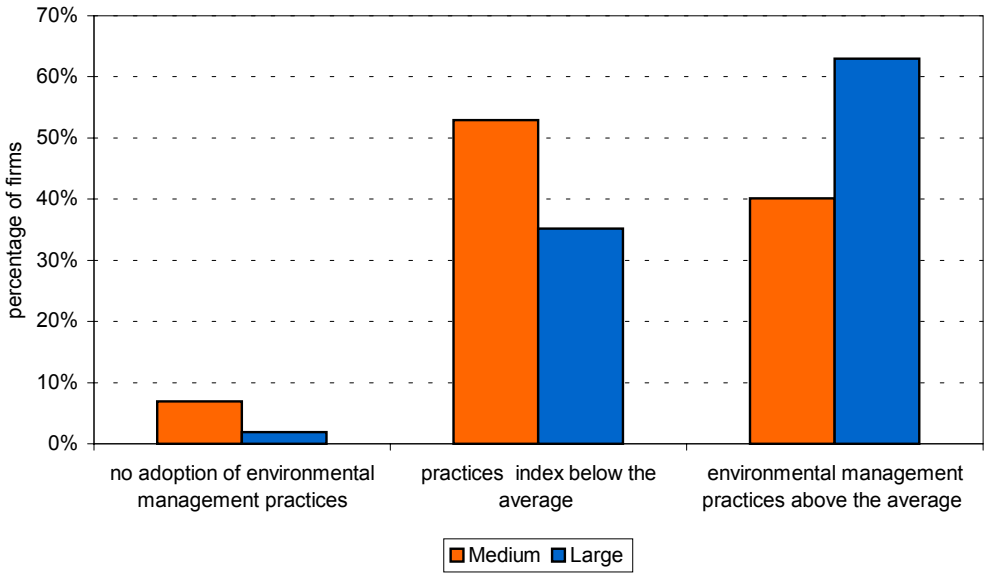
As you can see in Table 5 the mean value is of 685 employees with a distribution showing a large deviation and skewed to the right.

Table 5 - Statistics of Number of Employees

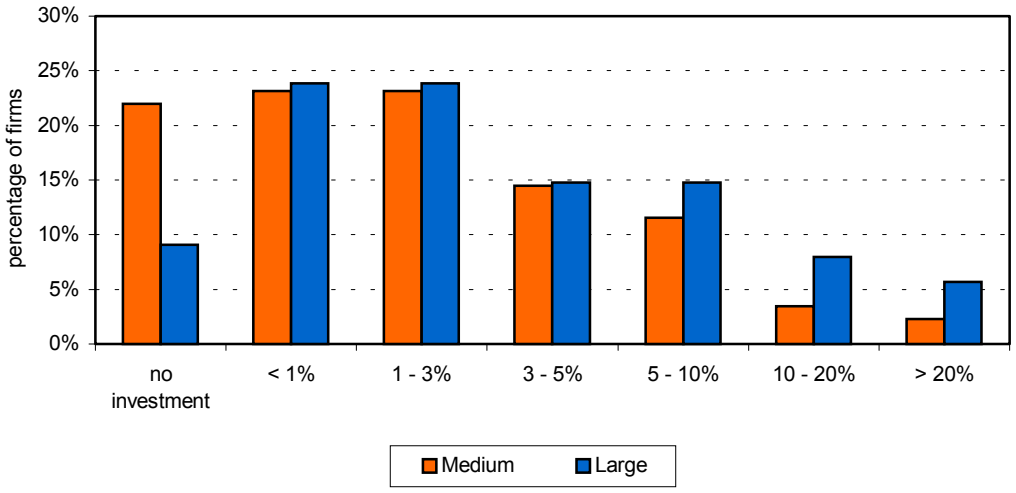
Variable	*Obs*	*Mean*	*Std. Dev.*	*Min*	*Max*
Employees	324	684.99	1000.20	100	8359

Graphs 1a to 1c present the evolution of our indicators against the size cut of medium and large firms by number of employees that represent 65 and 35%, respectively, of the sample. All three graphs show that the number of firms in each indicator varies positively with the number of employees, with less influence for investment and cost ratios.

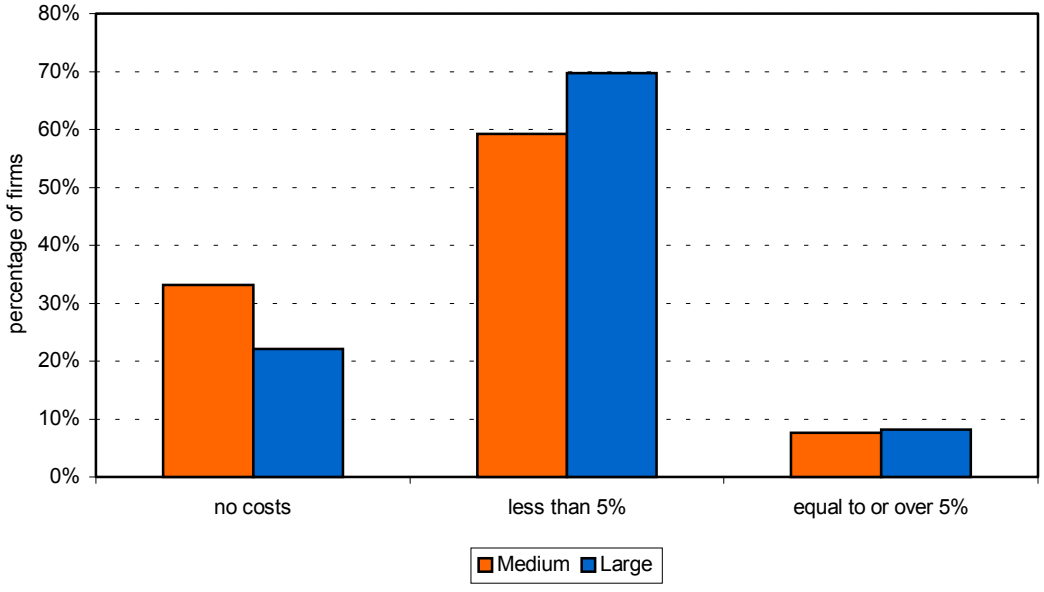
Graph 1a - Size by Number of Employees and Environmental Practice Index Ratio



Graph 1b - Size by Number of Employees and Environmental Investment Ratio



Graph 1c - Size by Number of Employees and Environmental Operational Cost Ratio



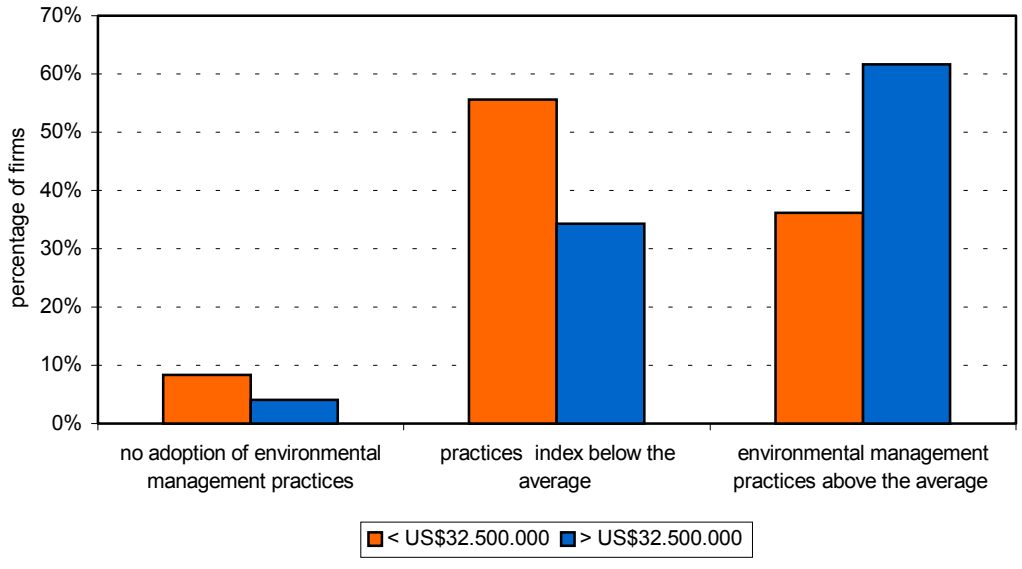
As Table 6 shows, the mean value of revenue is about US$ 70.0 million (equivalent to R$ 75 million) with also high deviation and skewed to the right.

Table 6 - Statistics of Revenues

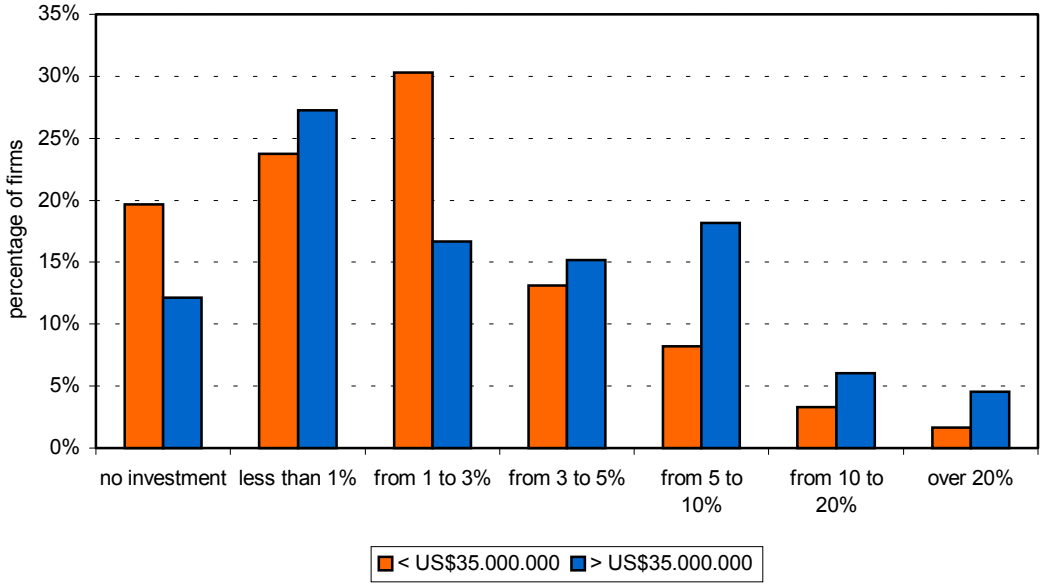
Variable	*Obs*	*Mean*	*Std. Dev.*	*Min*	*Max*
ROL (R$)	220	7,46E+07	1,90E+08	300000	1,81E+09

The same correlation observed from the number of employees could be expected for revenue in relation to our indicators. To simplify the analysis, we classified firms into large and medium if they are, respectively, above or below US$ 32.5 million, which correspond to the average revenue of the cut by size. As can be seen in Graphs 2a to 2c the same positive relationship is found with the exception of the bracket 1-3% of the investment indicator and also less for cost ratio.

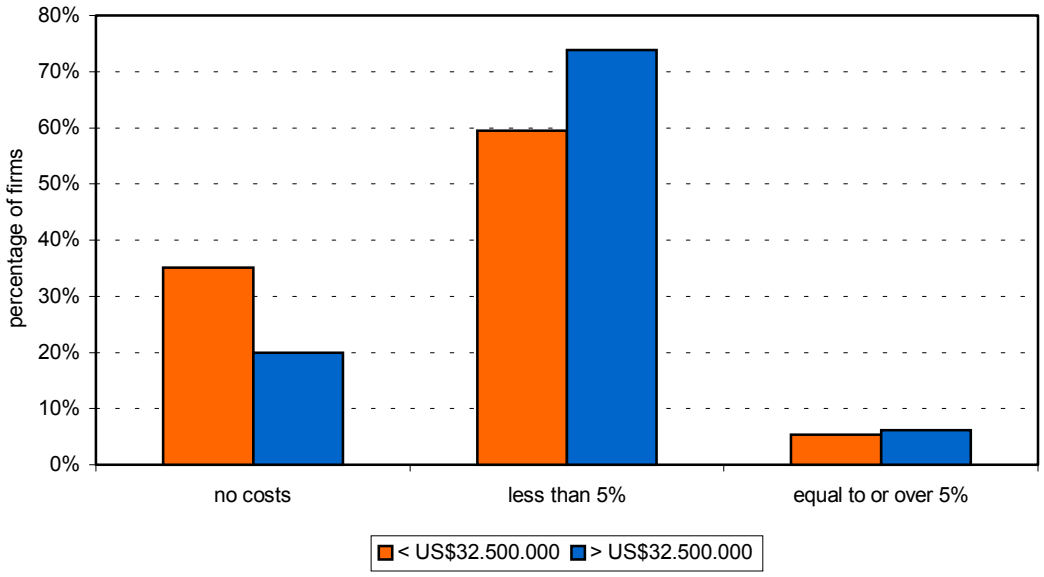
Graph 2a - Size by Revenue and Environmental Practice Index



Graph 2b - Size by Revenue and Environmental Investments



Graph 2c - Size by Revenue and Environmental Operational Costs

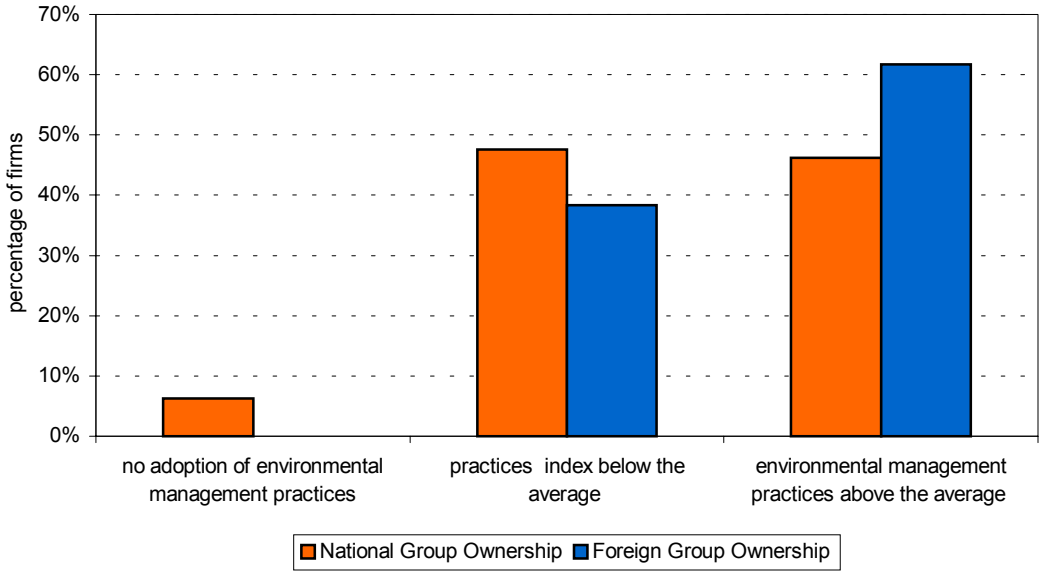


In both cases (number of employees and revenue) we will test, in our econometric exercises, both variables and combinations of them, in log form to smooth the highest values effects.

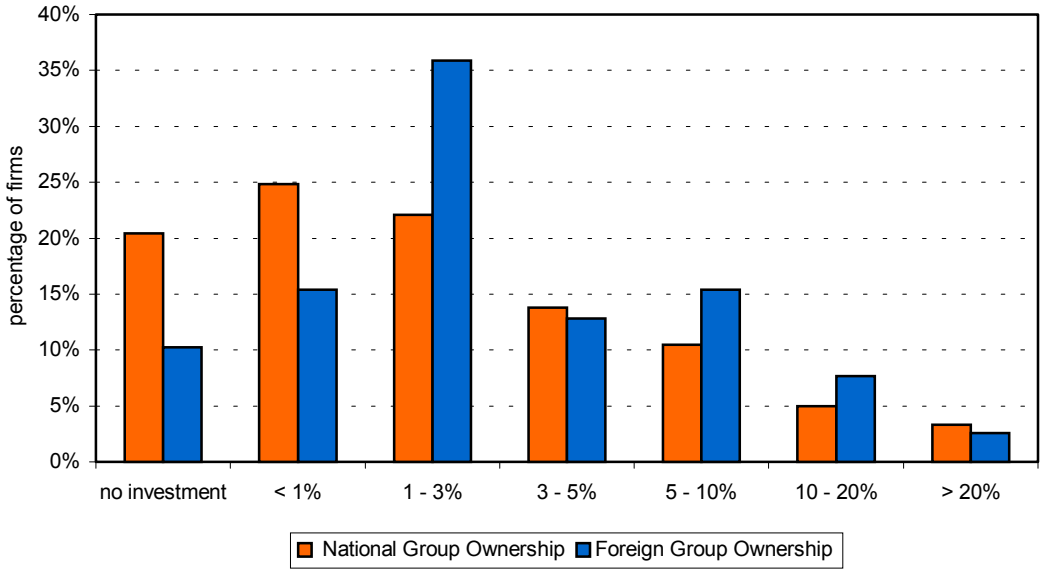
Origin of Capital: Firms that are part of international groups may be influenced by the headquarters' rules and procedures on environmental control. Since major international groups are based on rich countries, with tighter environmental restrictions, we could expect these firms to present better performance than those associated to national capital. In our sample, there are only private companies, and those parts of national groups are the majority of 82% while the foreign owned represent the remaining 18%.

In Graphs 3a to 3c, we observe that international groups are concentrated in high practice indexes but only in some investment brackets, and with less correlation to costs. This may suggest that international groups may be closer to optimum environmental control levels than domestic ones. In our regression models, we will use the two types of capital ownership, two dummies with the domestic one absent.

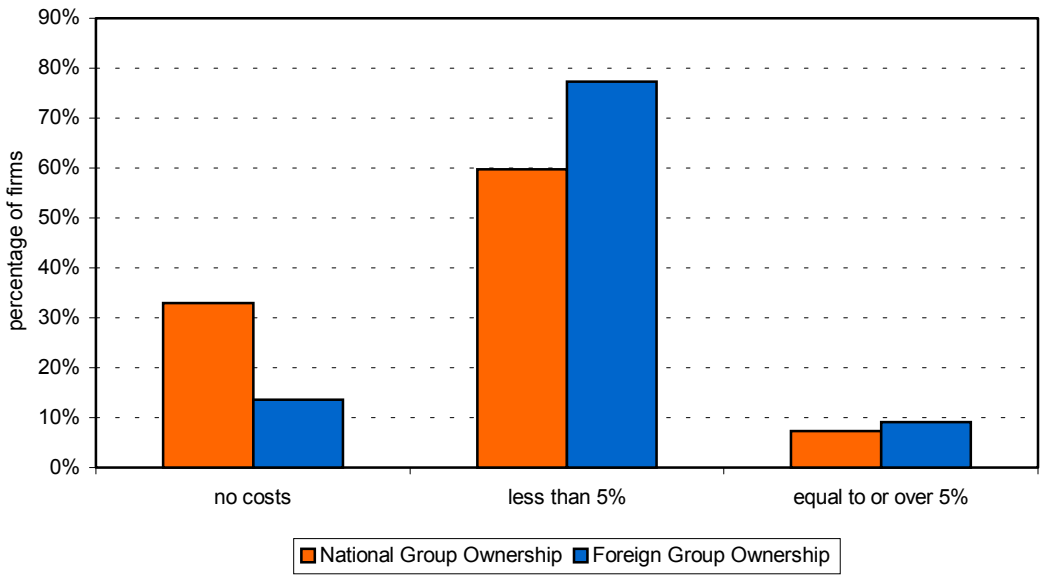
Graph 3a - Capital and Environmental Practice Index



Graph 3b - Capital and Environmental Investments

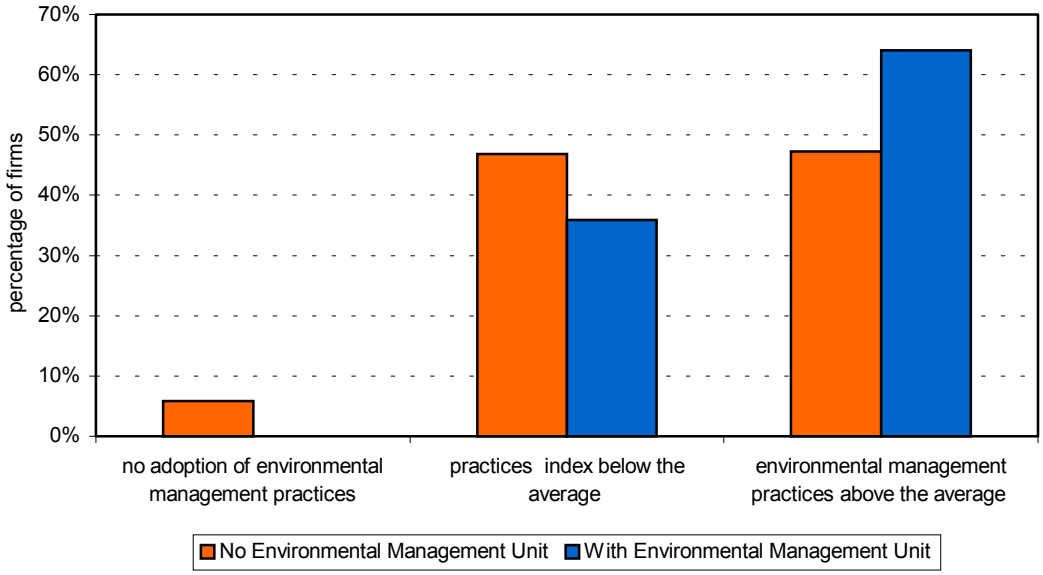


Graph 3c - Capital and Environmental Operational Costs

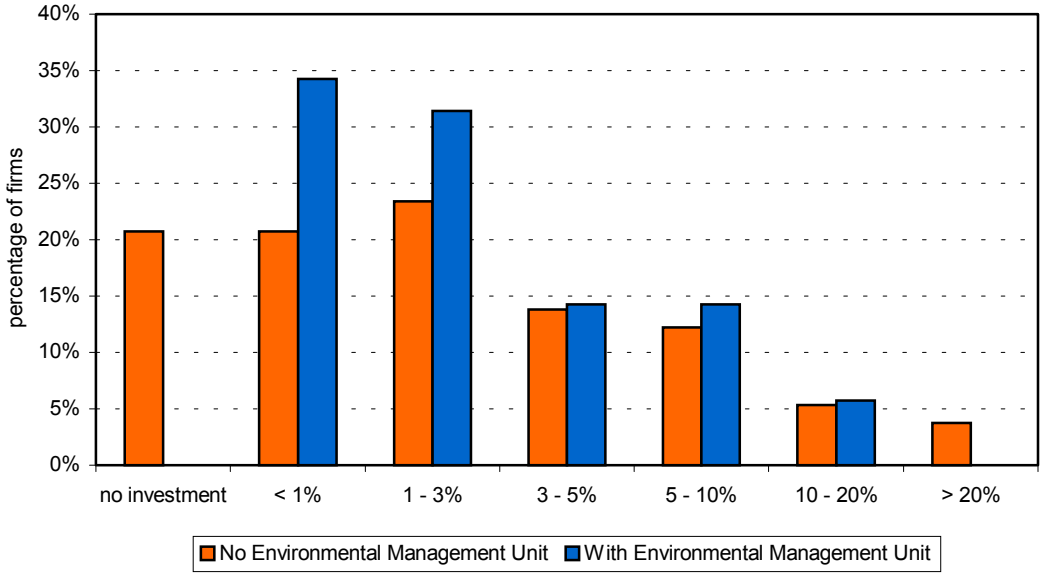


Environmental Management Unit: Firms may organize their environmental management practices and decisions under the same and single direction and, therefore, they may create a centralized environmental unit. It is ambiguous how unification of decisions affects performance when transaction costs vary, but we can expect to find these unified units more often in firms that have developed a great deal of environmental control procedures. As can be seen in Graphs 4a to 4c we observe that the existence of this type of unit is dominant in high practice indexes and less for higher brackets in investment and cost ratios.

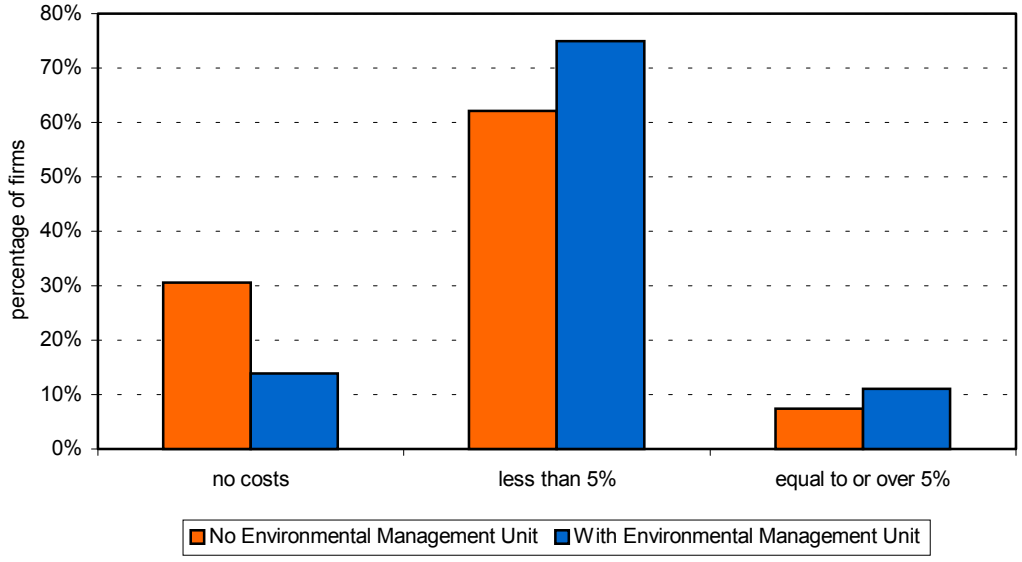
Graph 4a - Environmental Management Unit and Environmental Practice Index



Graph 4b - Environmental Management Unit and Environmental Investment



Graph 4c - Environmental Management Unit and Environmental Operational Cost



Sector: Pollution intensity is highly dependent on the type of output, processing technology and inputs. Therefore, it varies according to industrial activities. In high

pollution-intense sectors, besides the fact that pollution control can be costly, firms tend to attract more attention to their compliance status. According to the air and water pollution intensities estimated in Seroa da Motta (1994) we classified sectors as red, brown and green according to their degree of intensity, from high to low, respectively, as shown in Table 7. Firms in the brown sectors are almost half of the sample followed closely by the ones in red sectors. Green sectors are only covering about 14% of the firms surveyed. This color classification will generate three sector dummies with red absent in the regression.

Table 7- Sectoral Classification According to Pollution Intensities

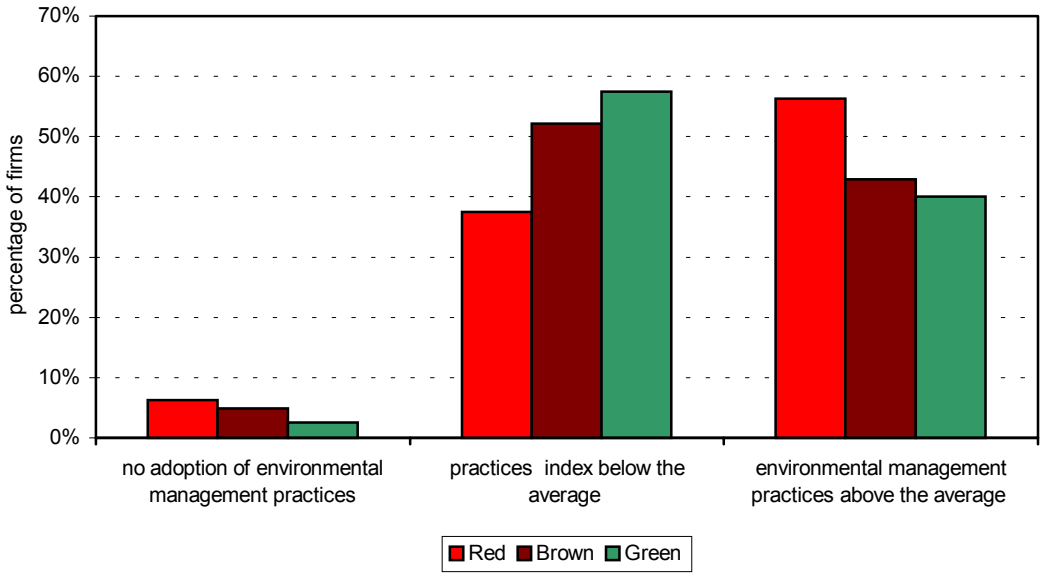
	"Green" Sector	*Percentage*
13	Electronic and Computational equipments	4.3
18	Rubber	0.6
23	Plastic	3.7
28	Tobacco	0.6
29	Printing	2.2
30	Others	1.9
	Total	13.3

	"Brown" Sector	*Percentage*
00	Mining	1.2
12	Machinery	5.9
14	Automotive Assembling	4.3
15	Wood	2.2
16	Furniture	2.8
24	Textile	6.5
25	Clothing	8.6
26	Food	14.2
27	Beverage	1.5
	Total	47.1

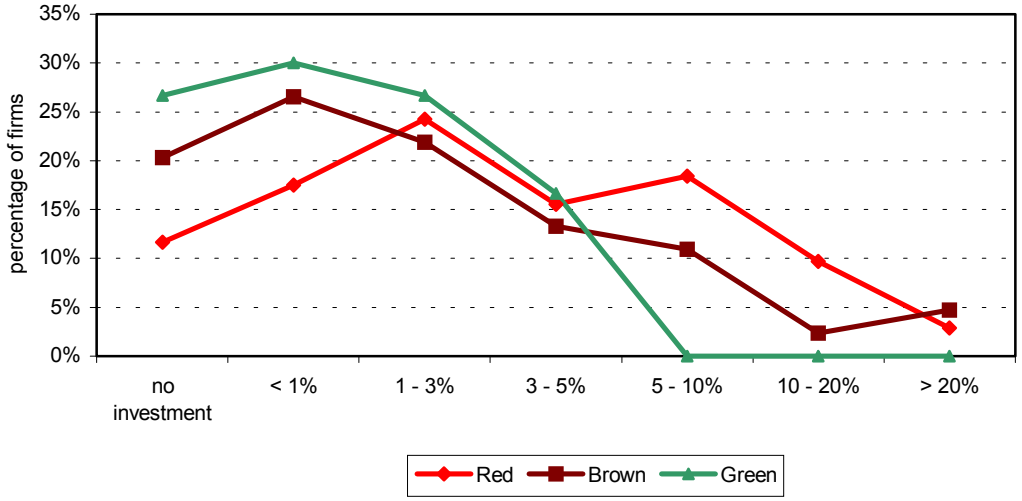
	"Red" Sector	*Percentage*
10	Non-metallic minerals	7.1
11	Metallurgy	11.4
17	Paper and Cellulose	4.3
19	Leather	2.2
20	Chemical	11.7
21	Pharmaceutics	2.5
22	Perfume, soap and candles	0.3
	Total	39.6

Graphs 5a to 5c show that at higher levels for all indicators, the red sector is followed in sequence by the brown and green sectors, indicating that the high pollution-intense sectors are the ones investing more, facing higher costs and adopting a greater number of practices in environmental control.

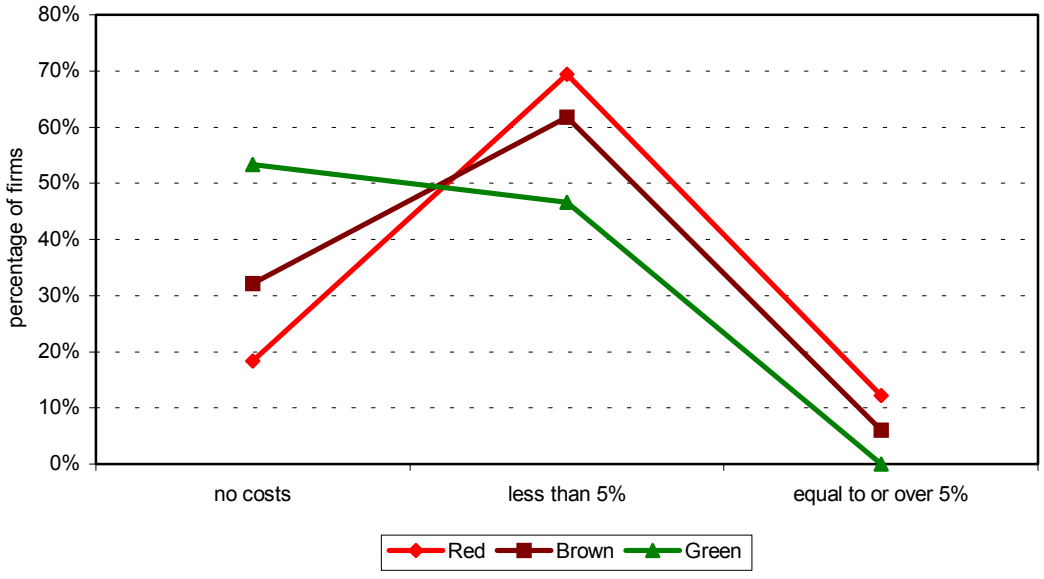
Graph 5a - Sector and Environmental Practice Index



Graph 5b - Sector and Environmental Investment



Graph 5c - Sector and Environmental Operational Cost



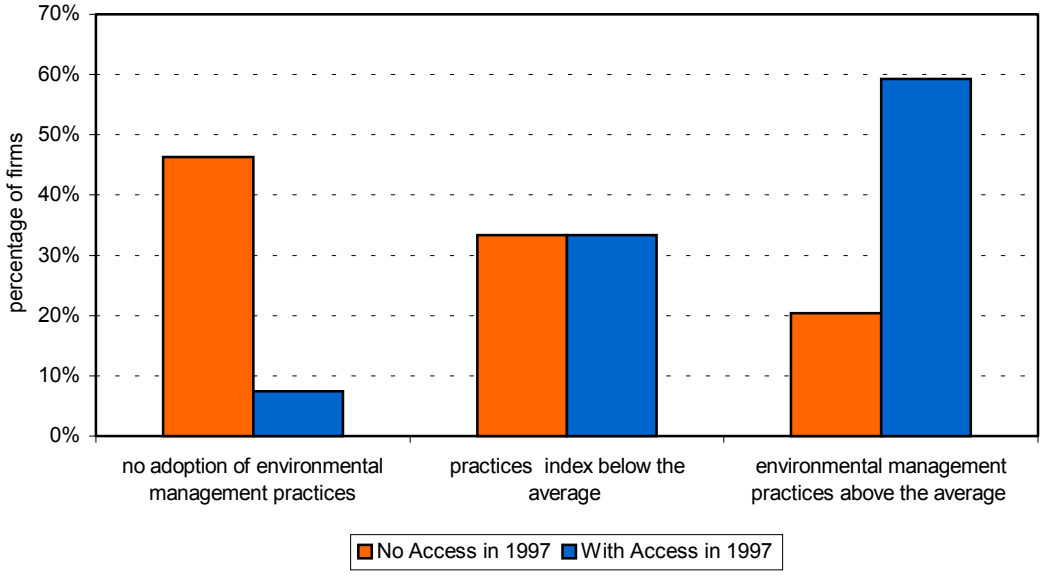
4.3.2. Market Opportunities

Variables that capture market opportunities with environmental control are associated to gains in competitiveness through supply factors, such as: cost reduction from credit and fiscal incentives to savings on energy, water and other inputs, and demand factors as the increase in market shares.

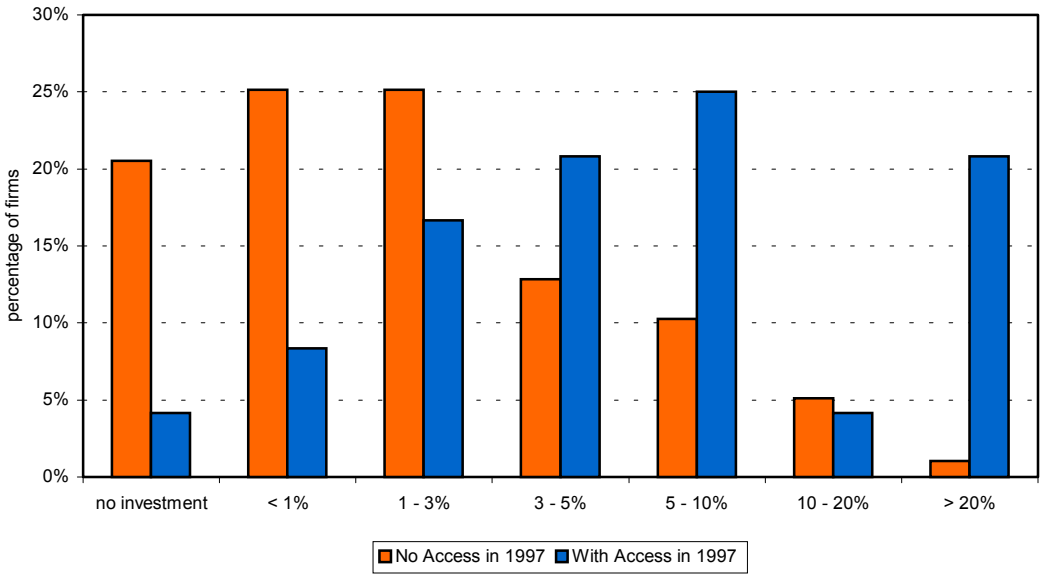
From the CNI survey, we can rely on proxies for subsidized credit, export markets and certification. In addition to that, we can also use responses associated to motivations for adopting environmental practices that are related to market incentives.

Subsidized financing: Access to subsidized financing schemes from governmental sources is expected to reduce the effective environmental investment and operational costs. In our sample, around 13% of the firms that made environmental investments had access to these schemes in the years 1996 and 1997, respectively. Credit subsidies seem to have great influence in high bracket levels of cost and investments ratios, except for the 10-20% bracket in the latter indicator. In the practice index only in the high levels, we find dominance. For the purpose of our regression exercises, we created two dummies for financing where the one related to access to credit incentive appears in the function.

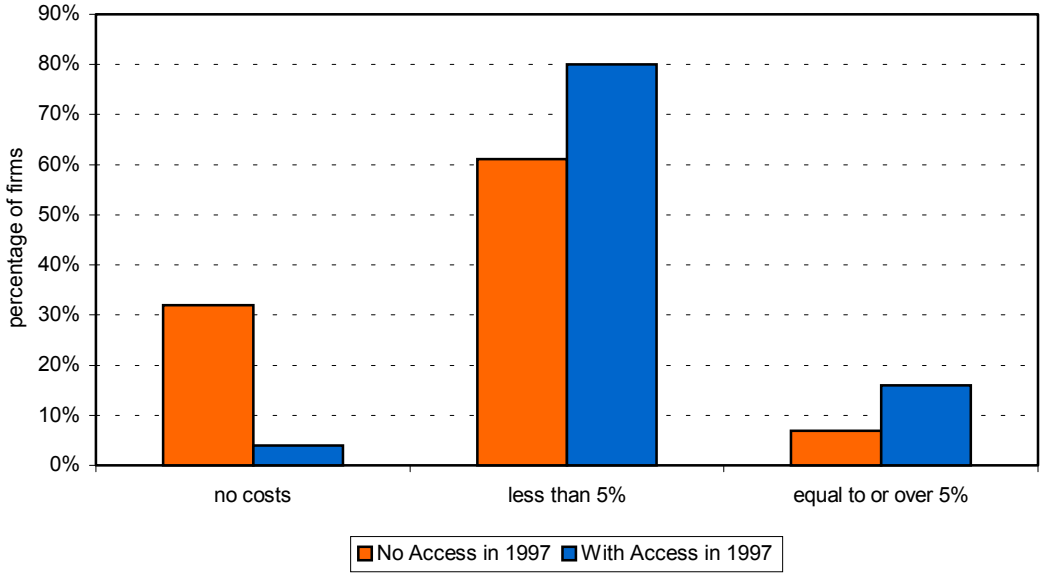
Graph 6a - Access to Subsidized Credit and Environmental Practice Index



Graph 6b - Access to Subsidized Credit and Environmental Investment



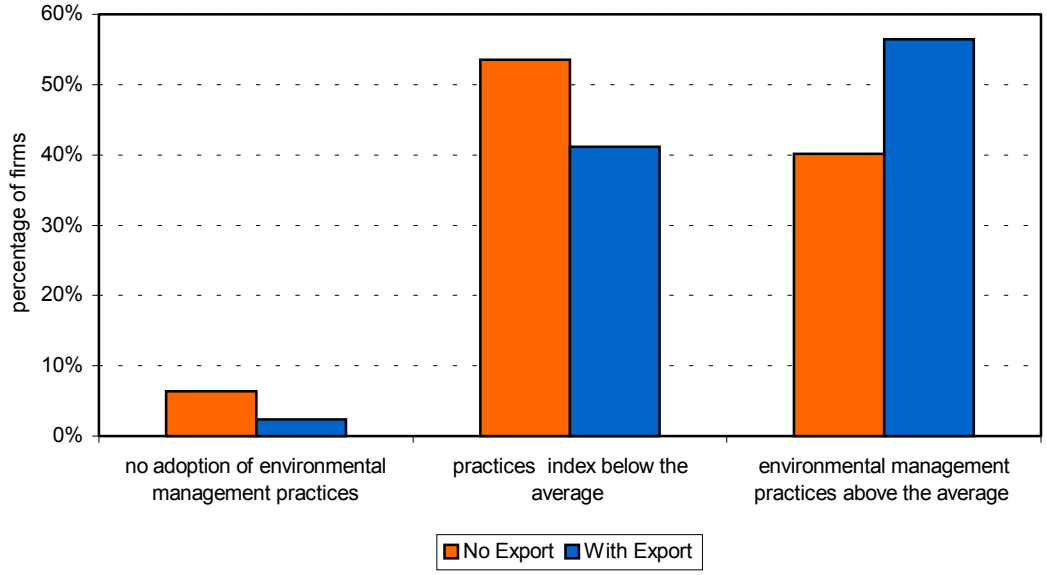
Graph 6c - Subsidized Financing and Environmental Operational Cost



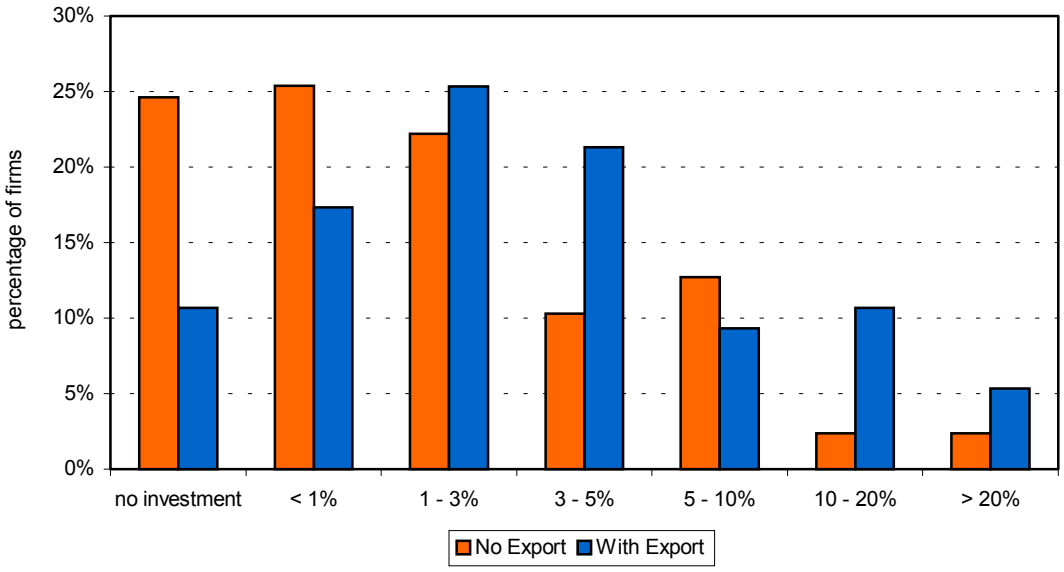
Export Market: Firms that concentrate their exports on markets with tighter environmental restrictions are likely to achieve higher environmental performance to capture their share. Therefore, we split our sample into two groups. One group of firms that export to OECD countries plus Asian countries and that has a proportion of exports over 10% of their revenue. This OECD-oriented group is about 36% of the respondent firms and the other 64% are placed in the second group. This classification will give rise to two dummies with the second group absent from the regression.

As can be seen in Graphs 7a to 7b, the OECD export-oriented firms shown greater influence over all indicators, except for the bracket 5-10% in investments.

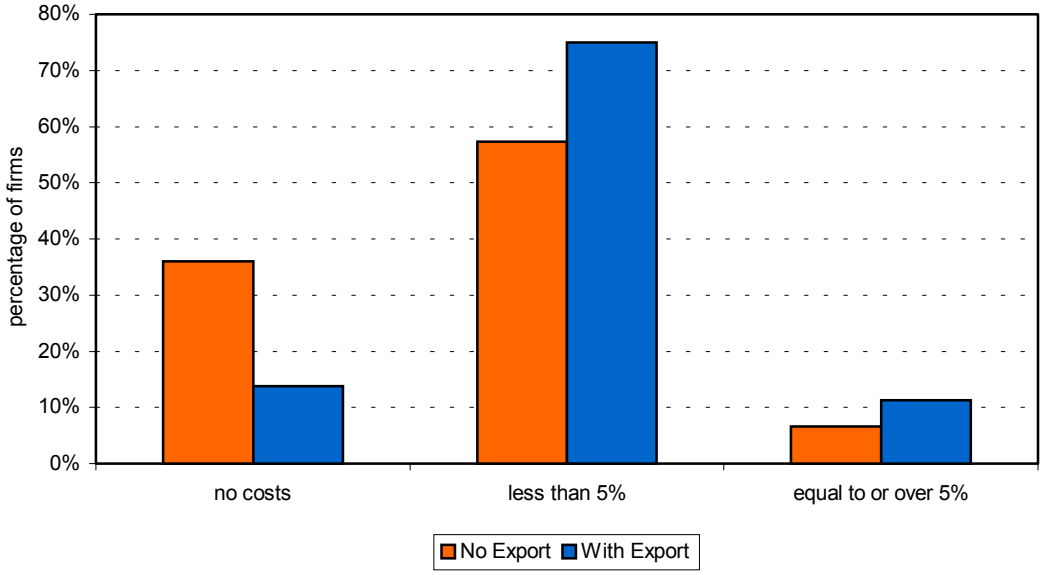
Graph 7a - Export Market and Environmental Practice Index



Graph 7b - Export Market and Environmental Investment



Graph 7c - Export Market and Environmental Operational Cost

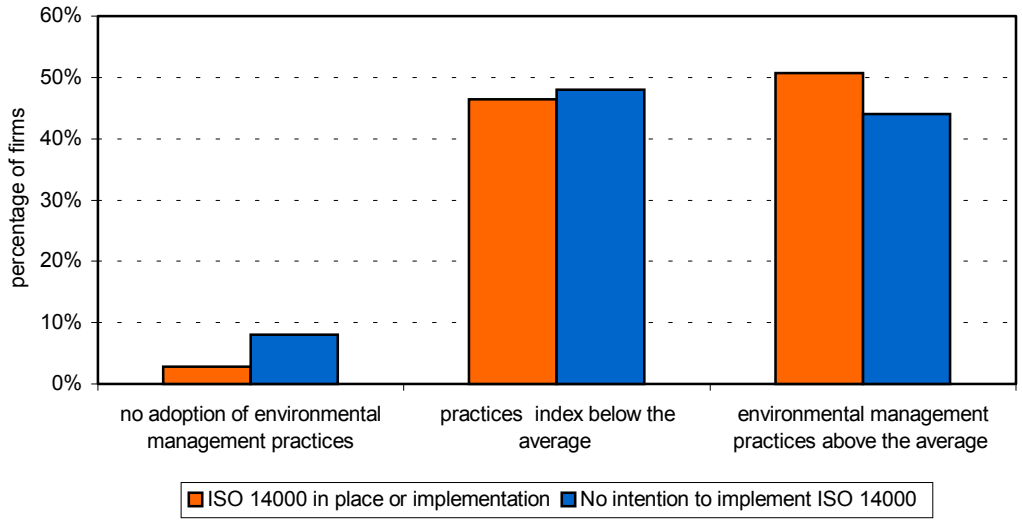


Environmental Certification: The certification of ISO 14 000 is not necessarily bound to the highest standards in environmental control but it improves the environmental image of the firm since ISO norms create management systems that allow buyers and suppliers to verify the firm's environmental performance. As bad compliers are not willing to open up their performance, the certification may be taken as an assurance for good environmental behavior and possibly open up market opportunities.

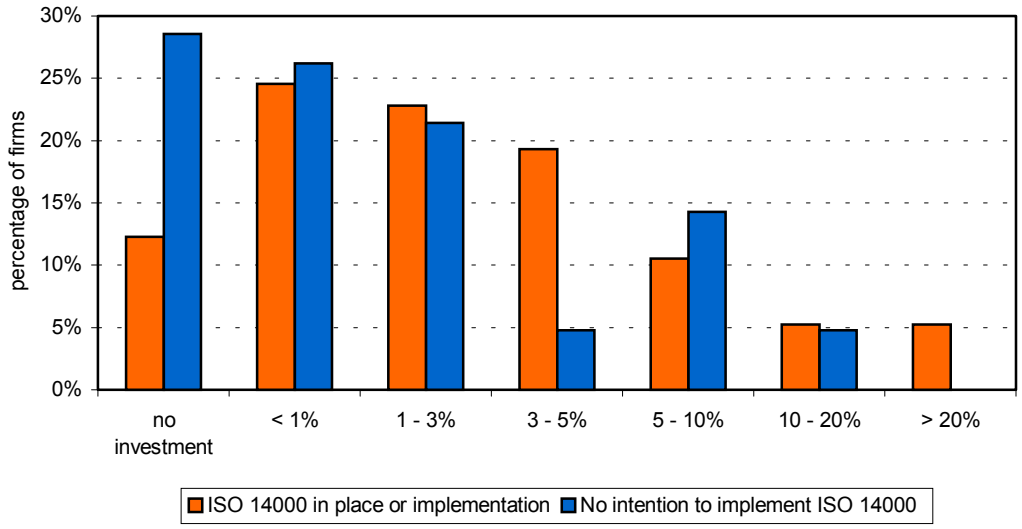
Adoption of ISO 14 000 is much lower than ISO 9000, not only for being more recent but also due to the fact that quality is still more important than environment in trade. Although only 22% of the surveyed firms acknowledged that they are already certified or in process of certification with ISO 14 000, a great proportion of 63% said that they are willing to have or they already have another environmental management system. Therefore, we split our sample into those that indicated no intention to have the certification, around

15%, and those that showed the intention to have it, which sums the remaining 85%. Graphs 8a to 8c, however, show that intention to certification is not very much related to any indicator.

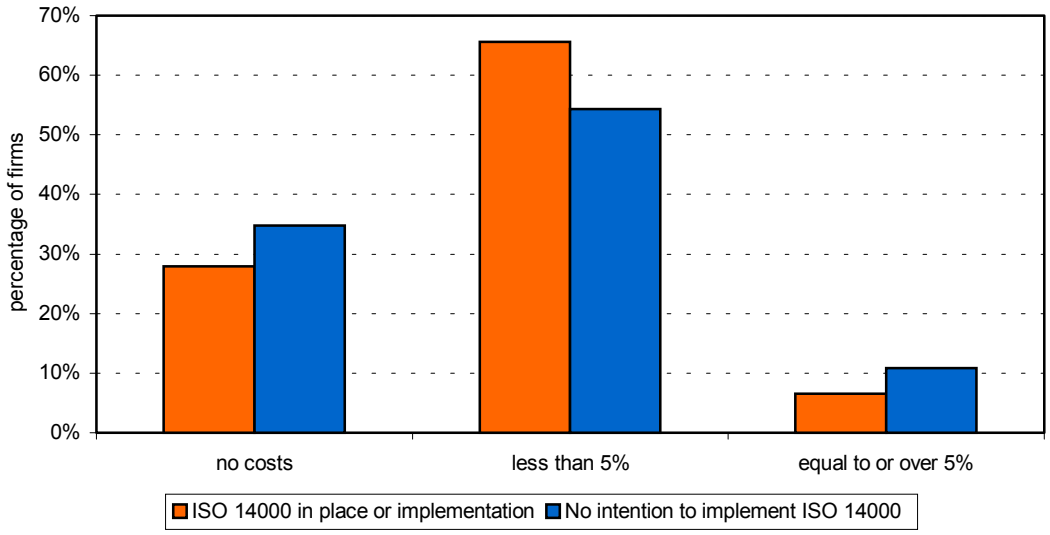
Graph 8a - Environmental Certification and Environmental Practice Index



Graph 8b - Environmental Certification and Environmental Investment



Graph 8c - Environmental Certification and Environmental Operational Cost



4.3.3. Regulation and Community Pressures

Governmental environmental agencies can apply sanctions on non-compliers, such as: penalties, denial of licensing, and closure. These sanctions can result from systematic inspections or from denouncements from community members and NGOs. In the CNI survey, firms indicate if they were sanctioned or not, and if so, the initial source of the applied sanction. Table 8 shows that community sources are only indicated by 13% of respondents whereas systematic inspection is 22% and the rest are also related to other regulator's actions. We aggregated these sanctions into one single variable since it is the actual sanction event that we are concerned with.

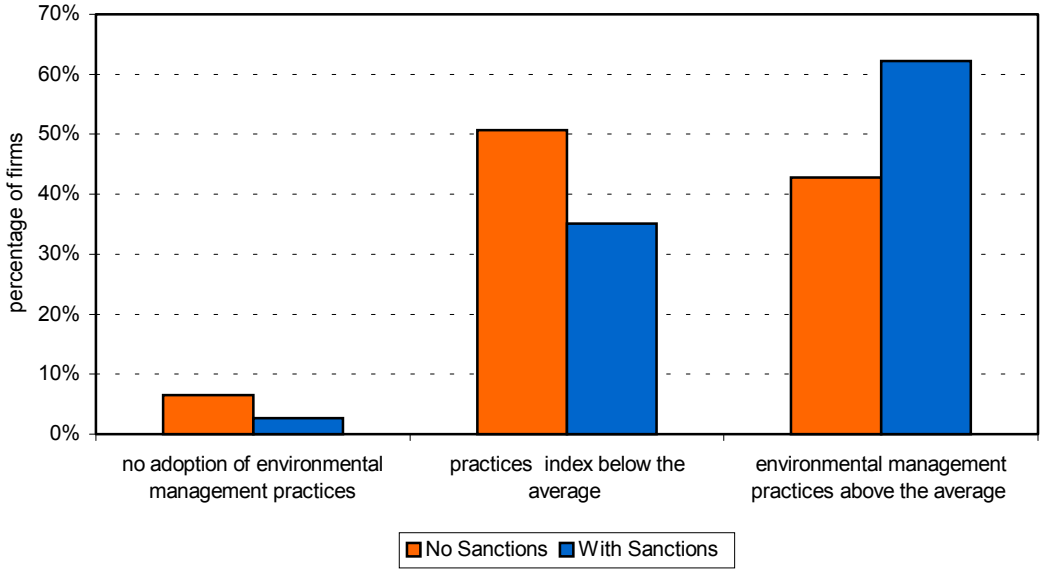
Table 8 - Frequency of Sanctions

Source of Sanctions	*Percentage*
Neighborhood	12
NGO	1
Environmental accident	7
Non compliance with agreements	5
Systematic inspection	22
Actions of the public attorney	2
No sanctions applied	49
Others	3

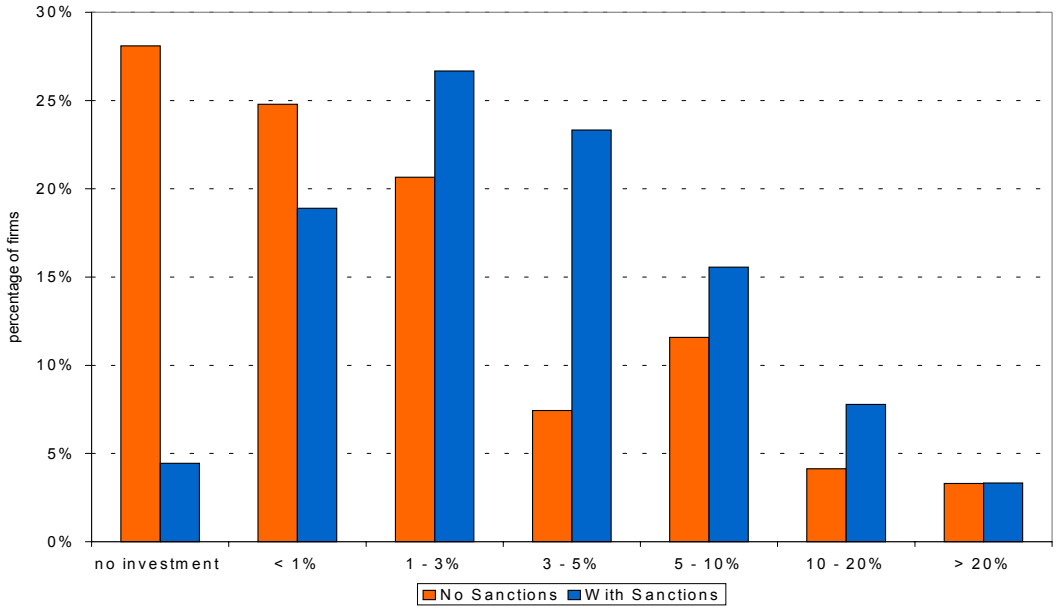
Since sanctioned firms that do not adjust their behavior may face very high penalties, including closure, we may expect that, once sanctioned, firms tend to make efforts to achieve environmental performance.

In Graphs 9a to 9c, we confirm that the number of sanctioned firms is concentrated in high levels of the indicators.

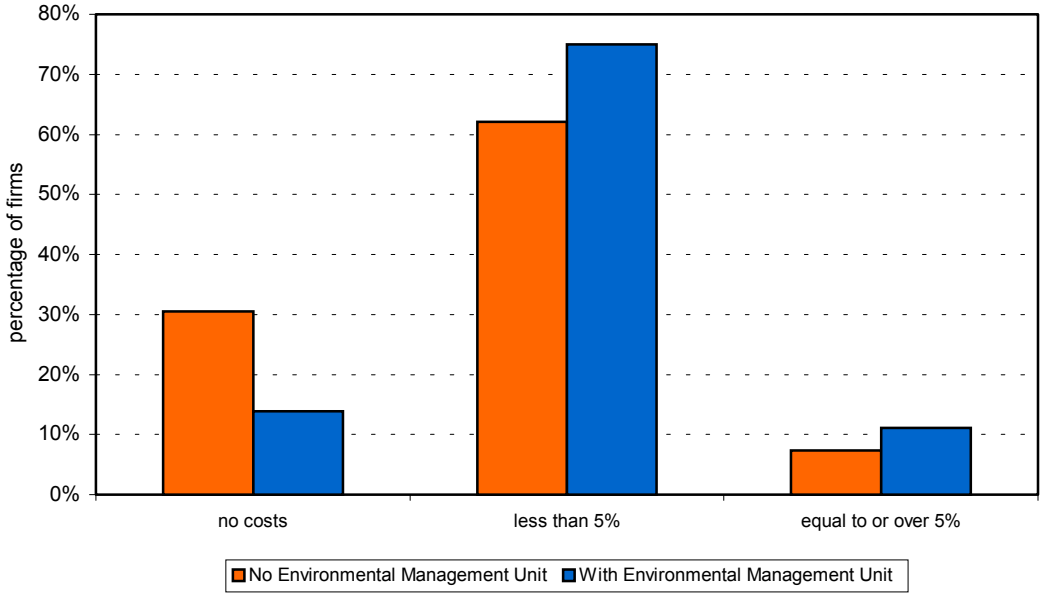
Graph 9a - Sanctions and Environmental Practice Index



Graph 9b - Sanctions and Environmental Investment



Graph 9c - Sanctions and Environmental Operational Cost



Motivations: In the CNI survey, firms were asked to indicate the most important motivations, up to three, that led them to the adoption of the environmental control practices already in place. Table 9 presents frequencies for these motivations. As can be seen, categories of formal regulation and market orientation show much higher frequencies than community-related aspects.

Table 9 - Motivations to Adopt Environmental Control Practices

Motivations to Adopt Environmental Control Practices	***Percentage***
To comply with licensing	18
To comply with norms and standards under inspection	18
To reduce production costs	13
To improve quality of the produced goods	6
To increase competitiveness of exports	2
To meet customer's demands	5
To meet financial institution's demands	1
To meet community pressure	6
To meet NGOs pressure	1
To meet the firm's social policy	20

Image	7
Other	2
No adoption	2

Due to restrictions in degree of freedom in our regressions[5], we will only apply five categories of dummies based on the motivations that will express if the firm has indicated or not this category with absence for other indications. For formal regulation, we aggregated motivations related to compliance with licensing, norms and standards, and for community-driven aspects we took community and NGOs pressure. For the motivation with highest frequency related to market-oriented issues, we created one specific category including financial aspects, since this aspect was also observed with actual data. The dummies were the following:

MotEPA - to collaborate with regulators

MotCOST - to reduce production costs

MotEXP - to increase competitiveness of exports

MotDEM - to improve quality of the produced goods

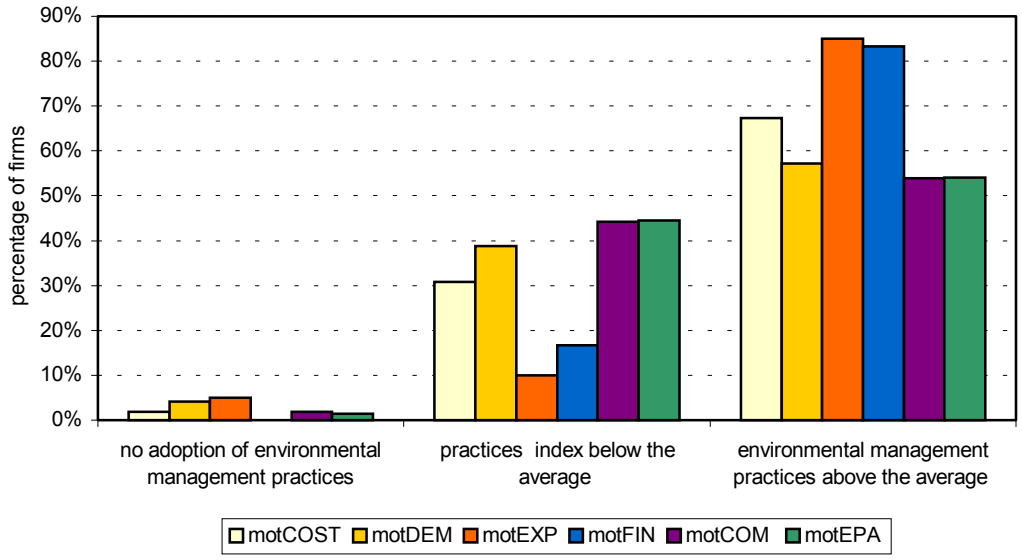
MotFIN- to meet environmental requirements from governmental financing agencies

MotCOM – to meet demands from community and NGOs

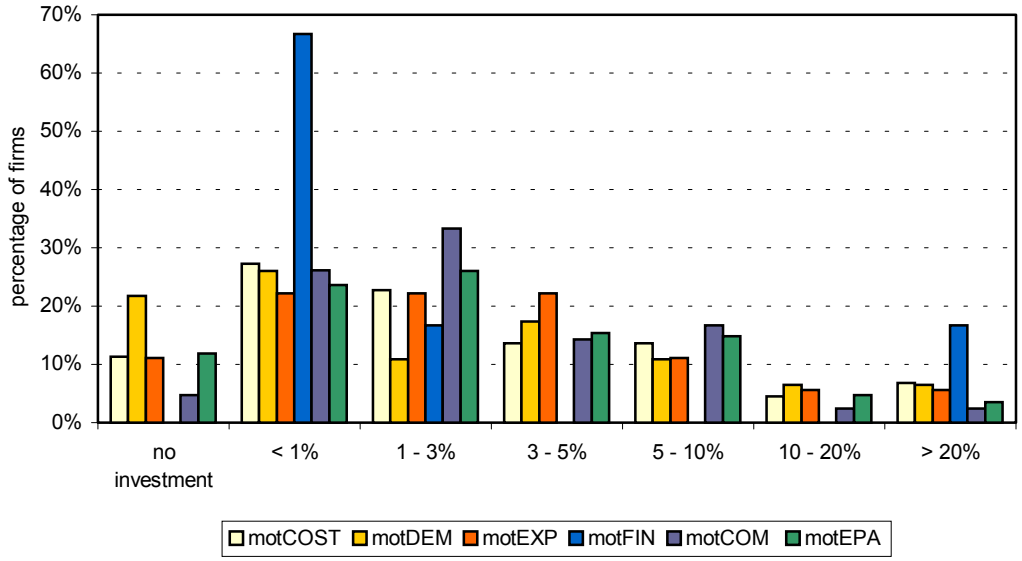
Graphs 10a to 10c show that motivations are hard to analyze in this bivariate relationships. However, cost saving and regulator and community pressure seem to be more consistently important in all high levels of indicators.

[5] That is, lack of number of observations to deal with larger number of variables.

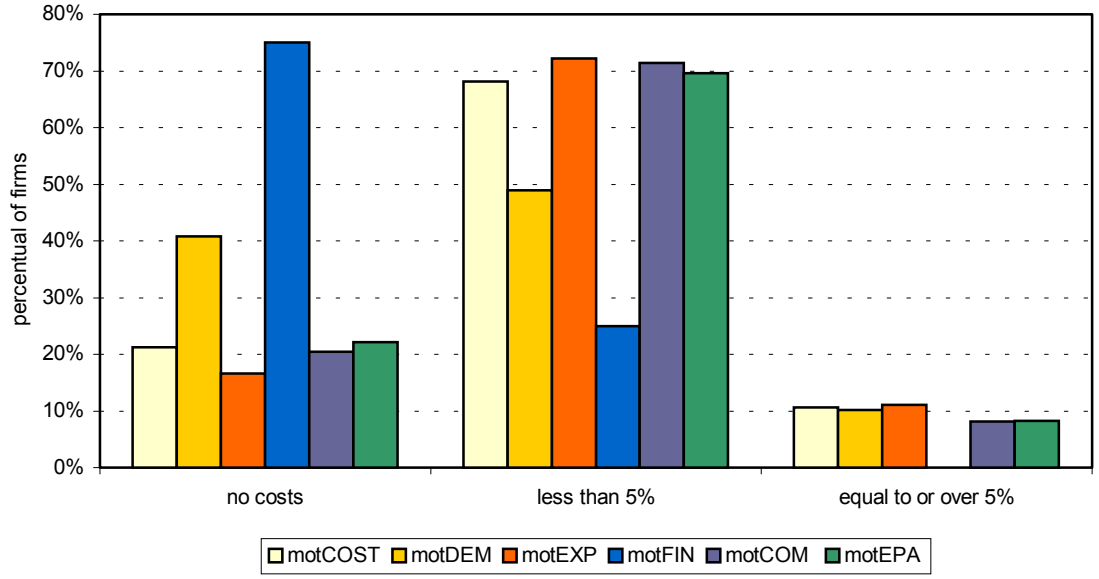
Graph 10a - Motivations and Environmental Practice Index



Graph 10b - Motivations and Environmental Investment



Graph 10c - Motivations and Environmental Operational Cost



4.4. Conclusions

The bivariate analysis above gives us one single dimension of the importance of each variable against our indicators of environmental performance. Based on that we could say that our survey represents an average firm that is over medium size undertaking high-polluting activities. This representative firm is domestically owned and domestic-market oriented and reckons very little on credit incentives to invest. It has built a relatively below average stock of practices that spends less than 5% of its total operational costs to function. About 1-3% out of its total investments in 1997 was devoted to environmental control with very little subsidized credit. These firms had almost 50% of chances of being sanctioned for non-compliance, mostly by systematic inspections and denouncements from the community. Besides inspections, also market opportunities motivated them to adopt environmental control practices.

To understand how much each feature influences each indicator and how their variations affect the decisions to achieve higher environmental performance levels, the next section presents applications of econometric models that treat all variables together in respect to the indicators. From this combined analysis, we will be able to determine each effect after controlling for the others.

5 - Identification of the Econometric Model

A polluting firm will minimize production costs equalizing compliance to non-compliance costs. Compliance costs can be measured by the efforts of the firm to comply with mandatory regulation.

The firm's compliance costs are given by its marginal pollution control cost that reflects its ability to comply in terms of the firm's characteristics (size, sector, origin of capital, etc) given by the vector **X**.

Non-compliance costs are avoided sanctions and losses of market premiums opportunities associated with high environmental performance.

Non-compliance faces costs due to penalties applied by regulators, payments resulting from judicial litigation from accidents and damages to third parties, compensations to community members and foregone market premiums. So the non-compliance marginal costs related to the sanctions applied by regulators, whether resulting from the regulator's inspection or pressure from community members and NGOs, is given by the vector **E**.

The market incentives (export demand with tighter environmental restrictions, subsidized credit, certification, etc) to increase environmental performance due to their affects on competitiveness (on sales or costs) given by a vector **M**.

If so, environmental performance (EPI) can be presented in a reduced-form expressed as:

$$\mathbf{EPI} = f(\mathbf{X, M, E}) \qquad (1)$$

The previous bivariate analysis gives us very interesting results on how the firm's characteristics, market incentives, formal regulation, and community affect, by themselves, our environmental performance indicator. To analyze how the interaction of these variables does affect environmental performance and how the effect of each one is conditional to the existence of the others, we can apply econometric techniques that will be discussed next.

We test our model to data considering the three indicators of environmental performance (PI) previously mentioned, namely:

1 – The level of environmental control practices that firms have in place in the year 1997. This is a constructed index vector that gives log values of a continuous variable that reflects a number of practices adopted by each firm summed up by the respective value of $(1-p_i)$ where p is the sample average frequency of practice i. (that is: $\ln \Sigma (1-p_i)$). This variable then reflects the level of environmental management practices of the firm (EMP) that assigns high values for practices that are less frequent. Firms are differentiated by the adoption of less standard practices that may reflect a higher environmental performance.

2 – The 1997 level of environmental investment ratio (EI97) is presented in seven percentage brackets related to total investments undertaken in the year.

3 – The 1997 level of environment-related operational costs ratio (EC97) is presented into three percentage brackets related to total operational costs.

As can be seen, the continuous variable on environmental practice index represents the current level of environmental management procedures built up over the years and it

reflects the total current effort of the firm on environmental management. It has the feature of a stock, although measured in no monetary dimension, and we cannot assume a possible relation between the variable levels and the costs of implementation of such practices.

In the case of the discrete variables on environmental investment ratio to total investments, we are dealing with financial efforts of the firm to improve environmental performance that takes place in 1997. It has, therefore, a dimension of flow economic variable affected by the previous level of investments, that is, the stock of investments.

Although the discrete variable on environmental operational costs also refers to 1997, cost level is also related to the current stock of investments.

Recalling expression (1), the independent variables **X**, **M** and **E** represent the factors affecting the indicators above cited. In our econometric exercises, we can then determine how much each of these factors can explain the applied environmental performance indicator after controlling for the other factors.

As discussed earlier, for **M** and **E** we have two distinct types of information from the survey. For **M** we have answers that indicate export markets, subsidized credit and adoption of certification, and also answers indicating if market opportunities (cost reduction, export market, suppliers, buyers preferences and the firm's image) have motivated the adoption of environmental control practices. The former reflect events actually observed whereas the latter are based on expectations of the results stemming from the adoption of these practices. The observed variables are less sensitive to the respondent's biases whereas the motivations can reveal rational expectations that do not appear in the observed answers.

The same we find for sanctions. Respondents acknowledge if they were sanctioned and in another question, they indicate if environmental compliance requirements and the community's pressure were motivations for the adoption of these practices.

Although positive, no very high correlation was observed between actual and motivated data[6]. Actual events are usually more appropriate to estimate econometric relationships, but in our case motivations may be important variables to correlate the performance indicators representing average number of practices (EMP). Regarding non-compliance sanctions, as said before, the Harrington paradox is explained by the strategy of the firm to avoid penalties, so that EPA will take them to the high inspection rate group. Therefore, in this case motivation can be explanatory, and firms may anticipate investments, as they would not in the case of a sole penalty-oriented behavior.

Expectations on market incentives, such as: cost reduction and increases in market share, may also induce investments. However, most of them can be more easily observed than avoided penalties. Our motivation market variables include an important market incentive that is related to the improvement of the firm's image that is not easily measured, and is not captured in our observed variable.

EMP may thus reflect investments through time, spurred on by motivations, whereas yearly investments may be more affected by observed sanctions. We test this hypothesis running regressions for both 1997 EMP and investments.

It must be also noted that investments and practices led by one motivation may have resulted in one non-expected consequence. For example, the motivation of cost reductions and good image may enhance efficiency and marketing aspects inducing higher exports.

Finally, we have to acknowledge that our regressions based on reduced-forms will be affected by simultaneity between non-compliance sanctions and market incentives (for example, supply of credit and environmental restrictions on export markets) and our performance indicators. That is, decisions on environmental control are made simultaneously with stronger regulation pressure and supply availability of market incentives. Because of that, not all independent variables being used can be regarded as fully exogenous and may be correlated to the omitted variables that are also affecting the performance indicators and, consequently, biasing results.

To deal with that, we could apply a simultaneous equation model where each of these functions is jointly estimated. This is not an easy and trivial task but other studies on this subject (Ferraz and Seroa da Motta, 2001 and Pargal, Mani and Hug, 1997), granted with more generous databases, have utilized two-stage models to control for simultaneity for, at least, one case of endogeneity. However, such approach is not undertaken here since we believe that our database does not have the variety of information in time and scope length to allow for that.

Tables 10 and 11 below present and describe all variables applied in our econometric exercises. Due to the kind of questions applied in the survey, only size (lnemp) and average number of environmental practices (EMP) are continuous. Other variables are dummies, that is, they just indicate if the firm is or is not classified in the relevant situation. An analysis of outliers is presented in the Annex.

[6] The highest correlation, around 0.35, was for motivations related to financing and sanctions.

Table 10- Dependent Variables

Dependent Variables			
Variable	***Description***	***Unit***	***Expected Sign***
EI97_7	Discrete variable with seven categories indicating the percentage of total investment related to environmental protection in 1997	0-6 dummy (0=no investment; 1 = < 1% ; 2 = 1-3% ; 3 = 3 - 5% ; 4 = 5 -10% ; 5 = 10 - 20% ; and 6 = > 20%)	+
EC97	Discrete variable with three categories indicating the percentage of total operational costs related to environmental control in 1997	0-2 dummy (0=no cost; 1= up to 5% ; 2 = > 5%)	+
EMP	Indicator of a weighted average number of environmental control	index in log form	+

Table 11- Independent Variables

Independent Variables			
		Characteristics of the Firm	
Variable	***Description***		***Expected Sign***
lnemp	Number of employees in December, 31st 1997	log of number of employees	+
rol	Net revenue in December, 31st 1997	log of R$ revenue	+
green	Low polluting-sector	0-1 dummy (1=yes)	-
brown	Medium polluting-sector	0-1 dummy (1=yes)	-
red	High polluting-sector	0-1 dummy (1=yes)	+
intship	Part of an international group	0-1 dummy (1=yes)	+
envunit	There is an environmental management	0-1 dummy (1=yes)	+
		Market Incentives	
Variable	***Description***		***Expected Sign***
fin1997	Access to subsidized credit to invest in 1997	0-1 dummy (1=yes)	+
ISO14	ISO 14000 already certified or in process of in 1997	0-1 dummy (1=yes)	+
expOECD	OECD and Asia export markets representing over 10% of total sales in 1997	0-1 dummy (1=yes)	+
motFIN	Motivation to adopt environmental control practices related to requirements from governmental	0-1 dummy (1=yes)	+
motCOST	Motivation to adopt environmental control practices related to production cost savings	0-1 dummy (1=yes)	+
motEXP	Motivation to adopt environmental control practices related to competitiveness of exports	0-1 dummy (1=yes)	+
motDEM	Motivation to adopt environmental control practices related to improvement in the quality of the produced goods	0-1 dummy (1=yes)	+
		Formal and Informal Regulation	
Variable	***Description***		***Expected Sign***
sanction	If the firm was sanctioned for non-compliance in 1997	0-1 dummy (1=yes)	+
motEPA	Motivation to adopt environmental control practices related to licensing and inspections	0-1 dummy (1=yes)	+
motCOM	Motivation to adopt environmental control practices related to community and NGO pressures	0-1 dummy (1=yes)	+

5.1 Adoption of Environmental Control Practices

We assume that the 1997 level of adoption of environmental control practices (EMP) is correlated to all the firm's characteristics, such as: size given by number of

employees (lnemp)[7]; origin of capital if it is national or international (intship); and sectors (green and brown).

In the three models, we used total revenue (lnrol) and revenue per employee (rol/emp) but both did not work. We then used number of employees that is usually applied in the literature perhaps because revenue is a kind of information usually avoided or distorted by respondents.

In regard to sanctions and market incentives we tried both sets of observable and motivated variables. For actual observations, we used access to governmental credit (fin1997), export to OECD (expOECD) and interest in certification (ISO14). Formal regulation and community pressure were all included in the variable sanction.

EMPa = f ([lnemp, intship, green, brown] (X) , [fin1997, expOECD, ISO14] (M), [sanction] (E)) (2)

In the second version we controlled for the variables related to motivations in avoiding sanctions as result from systematic regulators' inspections (motEPA), pressure from the community and NGOs (motCOM) and others related to the firm's competitiveness (motFIN, motCOST, motEXP and motDEM) replacing **M** and **E**. The equation is given by:

EMPm = f ([lnemp, intship, green, brown] (X) , [motFIN, motCOST, motEXP, motDEM] (M), [motEPA, motCOM] (E)) (3)

[7] As said in Section 2, we could use revenue figures but a reduced number of respondents gave this answer and we doubt its quality.

Table 12- Results for Number Environmental Practice Index (EMP)

	EMPa	EMPa	EMPm	EMPm
lnemp	0.17	0.15	0.17	0.17
	(3.13)***	(3.23)***	(4.33)***	(4.37)***
intship	0.05	0.19	0.21	0.21
	(0.44)	(1.68)*	(1.91)*	(1.93)*
envunit	0.13		0.00	
	(1.07)		(-0.01)	
green	-0.18	-0.23	-0.24	-0.24
	(-1.32)	(-1.70)*	(-1.89)*	(-1.87)*
brown	-0.27	-0.31	-0.29	-0.28
	(-2.57)**	(-3.20)***	(-3.16)***	(-3.18)***
fin1996	0.35	0.31		
	(2.31)**	(2.15)**		
expOECD	0.03			
	(0.23)			
ISO14	-0.14			
	(-1.29)			
sanction	0.23	0.24		
	(2.29)**	(2.55)**		
motFIN			0.33	0.33
			(1.92)*	(1.96)*
motCOST			0.44	0.43
			(5.40)***	(5.38)***
motEPA			0.20	0.20
			(1.86)*	(1.89)*
motCOM			0.27	0.27
			(2.71)***	(2.74)***
motEXP			0.25	0.24
			(1.83)*	(1.87)*
motDEM			-0.01	
			(-0.13)	
AF8-cons	4.39	4.51	4.03	4.02
	(14.50)***	(16.85)***	(14.82)***	(14.95)***
Observations	169	201	241	242
R squared	0.20	0.18	0.25	0.25
Root MSE	0.62	0.64	0.63	0.63
Prob > F	0.000	0.000	0.000	0.000

Robust t-statistics in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 12 presents the results of both regressions for the indexes EMPa (with actual sanctions and market incentives) and EMPm (with motivations to avoid sanctions and capture market incentives). The first column for each regression shows full regression results, and the second only shows the variables that remained significant after progressive deletion of non-significant variables. In both cases, we applied the OLS model.

The model EMPm provides a higher robust fitting to the data, with adjusted R^2 = 0.25 in the final form, than the respective R^2 of 0.18 estimated in the form EMPa. Since size is a continuous variable in log form, its coefficients are direct elasticity values. The discrete variables show shifts in the function of the relationship between EMP and the continuous variables (only size in this case) over the medium values. That is, how EMP would change if the dummies took the value of 1. Note that the dummy variables in the regression are the ones that coefficients are related to the absent one.

In both specifications size (lnemp), origin of capital (intship) and sanctions variables are significant and show the expected sign, confirming that larger firms, with foreign capital that either faced sanctions or wish to avoid them, tend to adopt a greater number of environmental control procedures. The size results confirm most of the hypothesis put forward in the previous section about plausible influence of these variables, assuring results found in other studies. As we can see in Table 12, size has quite similar elasticity in both models with 0.15 in EMPa form and 0.17 in the EMPm. In other words, 1% increase of the number of employees over the mean value is motivating 0.15 or 0.17% increase in the index of environmental practices.

Nevertheless, the relevance of foreign capital has been refuted in most studies that otherwise confirm the lower performance of state-owned companies. Since we do not cover public companies, and their role is quite small in Brazil today, we have been able to show

this trend towards foreign-controlled companies. Although the significance of the intship variable is quite robust in EMPm, it only turns out significant in EMPa model when other non-significant variables are dropped out.

Sectoral characteristics are also relevant as the coefficient of green and brown sectors are in negative to the absent red sector. That is, as expected, less pollution-intense sectors require a lesser number of control practices than more pollution-intense ones. On the other hand, perhaps due to sector misclassification errors, green sectors coefficients are, in both models, slightly higher than the brown ones.

Centralized environmental management unit is not significant but is showing a positive sign. In turn ISO 14000 certification, although is also not significant, perhaps due to its recent introduction and adoption, is surprisingly presenting a negative sign.

Another important result is the positive and significant coefficient of access to public credit (fin1996) to finance environmental investments and the EPA sanction level (sanction) in the EMPa model.

In the EMPm model, not only motivations to access public credit (motFIN) and to avoid EPA sanctions (motEPA) are also positive and significant as well as their magnitudes are quite close to the similar ones in the EMPa.

Also in the motivation model, the coefficients of motivations to save production costs (motCOST), to attend demands from community and inspections (motCOM) are also positive and significant. However, motCOST is by far the largest coefficient followed by motFIN whereas the others are quite equivalent. Although the variable related to quality of produced goods (motDEM) is not significant, the other motivation results are closer to what one could expect on market influences on environmental performance.

However, it is interesting to note that access to governmental credit, conditioned to environmental compliance, is playing an important role in the environmental performance of the Brazilian industrial sector. This evidence will be stronger in the analysis of investments presented later.

Note that we do not control for informal negotiations between community and firms, but the significance and magnitude of motCOM is confirming that indirect pressure from communities and NGOs is also relevant in the environmental performance of industrial firms.

In addition to that, differences in the magnitude of dummies' coefficients in the EMPm form, though not fully comparable, are indicating that sanctions from systematic regulator's inspections play a more important role than community pressure. These findings may suggest the confirmation of the Harrington paradox in environmental compliance in Brazil. Environmental management in industrial firms in Brazil is very concerned with trying not to be in the regulator's bad list and thereby facing a higher probability rate of inspections and high sanction levels.

The fact that firms are actually exporting to OECD countries, represented in the variable expOECD, did not show explanatory power in the EMPa model, although motivations to increase competitiveness did instead. This can be explained by the recent perception of environmental restrictions on the export markets.

It must be also noted that we do not observe in our database any variable that could be related to direct pressure from the community and NGOS to set informal negotiations and compliance with firms[8]. Previous studies done in Southeast Asia (Pargal and Wheeler,

[8] The best way to deal with this phenomenon would be an observed variable on direct negotiations. Another possibility often utilized in the literature is to rely on data from income, education and number of NGOs

1996, Hettige *et al*., 1996 and Panayotou, Schatzki and Limvorapitak, 1997) have found evidences on this link. The indirect via way was, however, found in Mexico, other high-income level developing country, by Dasgupta, Heitige and Wheeler (2000), when they also applied a model based on environmental management system indexes. We expect that this indirect relationship is more plausible in Brazil, and it has already been confirmed in Ferraz and Seroa da Motta (2001), who analyzed the industrial environmental investment decision in São Paulo, the most developed state in Brazil.

Similar to our findings in the motivation form, the São Paulo study also found evidences that firms are capturing market opportunities, contrary to the findings of studies carried out in other developing countries based on environmental management and investments (Dasgupta, Heitige and Wheeler, 2000 and Panayotou, Schatzki and Limvorapitak, 1997).

5.2 Environmental Investments

Now we turn to the analysis of the 1997 investments (EI97). Since investments are related to past investments, we should account for that using any information that represents past investments. We cannot use the index EMP since it also refers to 1997, and that would cause serious statistical problems. If we include this 1997 EMP variable, its importance to the 1997 investments will be overestimated. In econometric terms, the index EMP variable cannot be treated as exogenous and the random error in investment regressions would be correlated to this explanatory variable and, consequently, estimators

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located in the neighborhood of the firm that are suppose to influence local pressure. We cannot assure, though, that such pressures would be directly negotiated with non-complier firms.

will not be consistent[9]. The survey also does not allow us to find instrumental variables that explain stock without being correlated to investment.

Another way to proceed is to use lag values of investments, that is, information on past investments. The survey indicates the firms undertaking investments in 1996 and then we will control for the firms that undertook investments in 1996 (inv96)[10]. Although it is certainly a short lag distribution, it is the only resort we can apply with our database.

Following the same arrangements of variables applied in the EMP equations, we use both data on **M** and **E**. The regressions can be expressed as:

EI97a = f (inv96, [lnemp, intship, green, brown[(X), [fin1997, expOECD, ISO14] (M), [sanction] (E)) (4)

EI97m = f (inv96, [lnemp, intship, green, brown] (X) , [motFIN, motCOST, motEXP, motDEM] (M), [motEPA, motCOM] (E)) (5)

Since EI97 is a discrete variable with seven dummies we will use an ordered logit model, that relates probabilities of firms undertaking investments in each bracket with our independent variables[11]. Table 13 presents both forms of regressing investments, with full results in the first column, and the second one presenting results after non-significant variables being dropped. Although interpretations of marginal effects are difficult in ordered forms, Table 14 shows these ratios that represent how much the probability of the firm to undertake environmental investments increases when there is a variation of 1% in the continuous variable or the discrete variable changes value (from 0 to 1, per example).

[9] We ran the EI97 regressions with fitted values, and residuals, of EMP regressions and coefficients of residuals were statically non zero at more than 95% of confidence interval.

[10] Although we had 1996 investments in the percentage brackets, we did not use them to avoid too many dummies that would make analysis of results too difficult.

[11] In fact, logit applies the log of the likelihood function $[P_i /(1-P_i),]$ where P is the probability of event i. We also ran ordered probit and results were pretty much the same showing robustness of our models.

Average changes in probability are easier to understand and our analysis will rely mostly on them[12].

Fitting is similar and quite high in both forms, 0.24-0.27, for cross-section studies, although this is mostly due to the high correlation between investments in 1997 and 1996. In Table 14, we observe that marginal effect of inv96 is dominant.

As can be seen, both models capture influences of past investments and sectoral differences with the right signs and magnitudes, which are, in fact, very similar. Relevance of past investment is saying that the firms that invested more in 1996 are also the ones with a high investment ratio in 1997. Therefore, the commitment to environmental performance requires continuous efforts in investments. This is also true if we consider that high capital stock in environmental management implies high turnover and depreciation charges to keep constant the flow of capital services.

The same consistency is not found in both models with subsidized credit from governmental sources that have the expected sign in the EI97a but not in the EI97m. This implies that external and cheap sources of financing in 1997 explain investment decisions in 1997 but motivations to attend environmental requirements of financing sources reduces the chances of investing that year. This motivation creates incentives for the adoption of control practices, as already shown in the motivation form of EMP above, but it does not trigger the same effect for the 1997 investments.

Cleaner activities in the green and brown sector demand relatively less investment efforts than industries in the red sector (the absent variable). In other words, in the short run pollution intensity plays a more important role than other characteristics. Table 14 says that

[12] The sign of the coefficient is the same in the highest bracket and its opposite for the lowest bracket. In the middle, signs can change closer or further.

marginal effects of sectors are relatively higher in lower brackets. Note that certification again is not captured in any model.

In the EI97a model, investments are also very sensitive to sanctions while in the motivation form they are not, although when the number of adopted practices is measured, as in the EMP modes, motivation to avoid sanction is relevant. This result, however, may indicate that in the short run, investment decisions are only affected by actual sanctions. This can be another evidence of the Harrington paradox in Brazil. Firms build up their environmental control systems with motivations to avoid sanctions but when sanctions actually occur, they become an important determinant in the investments in order, perhaps, to change firm's classification as bad compliers and avoid high enforcement sanctions.

Table 13- Results for the Environmental Investment Ratio (EI97)

	EI97a	EI97a	EI97m	EI97m
inv96	6.99	6.12	7.25	6.37
	(4.81)***	(5.28)***	(5.28)***	(5.93)***
intship	0.52		0.30	
	(1.19)		(0.82)	
envunit	-0.26		-0.24	
	(0.69)		(0.60)	
green	-1.48	-1.21	-1.05	-1.02
	(2.45)**	(2.37)**	(2.28)**	(2.68)***
brown	-0.84	-0.7	-0.71	-0.66
	(2.39)**	(2.11)**	(2.22)**	(2.28)**
FIN1997	1.68	1.81		
	(3.21)***	(3.53)***		
expOECD	0.71	0.67		
	(2.12)**	(2.13)**		
ISO14	0.36			
	(0.93)			
sanction	0.32	0.61		
	(0.93)	(1.85)*		
lnemp			0.35	0.45
			(2.45)**	(3.29)***
motFIN			-2.31	-2.19
			(1.73)*	(1.96)**
motCOST			-0.08	
			(0.24)	
motEXP			0.12	
			(0.21)	
motDEM			0.14	
			(0.36)	
motEPA			0.23	
			(0.57)	
motCOM			-0.15	
			(0.45)	
Observations	162	179	208	217
Prob > chi2	0.00	0.00	0.00	0.00
Pseudo R2	0.26	0.27	0.25	0.24
Log likelihood	-217.59	-237.86	-278.28	-294.09

Robust z-statistics in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 14- Marginal Effects of Environmental Investment Ratio

EI97a								
Variables	**Average Change**	**no invest**	**less than 1%**	**from 1 to 3%**	**from 3 to 5%**	**from 5 to 10%**	**from 10 to 20%**	**over 20%**
inv96	0.24	-0.82	0.09	0.31	0.19	0.14	0.05	0.03
green	0.07	0.07	0.18	-0.14	-0.06	-0.04	-0.01	-0.01
brown	0.05	0.03	0.14	-0.07	-0.05	-0.03	-0.01	-0.01
fin1997	0.12	-0.04	-0.37	0.06	0.14	0.13	0.05	0.03
expOECD	0.05	-0.02	-0.14	0.07	0.05	0.03	0.01	0.01
sanction	0.04	-0.02	-0.13	0.06	0.04	0.03	0.01	0.01
EI97m								
Variables	**Average Change**	**no invest**	**less than 1%**	**from 1 to 3%**	**from 3 to 5%**	**from 5 to 10%**	**from 10 to 20%**	**over 20%**
inv96	0.24	-0.83	0.09	0.32	0.18	0.15	0.05	0.03
lnemp	0.22	-0.01	-0.01	0.05	0.03	0.02	0.01	0.01
green	0.06	0.05	0.18	-0.12	-0.05	-0.03	-0.01	-0.01
brown	0.05	0.02	0.14	-0.07	-0.04	-0.03	-0.01	-0.01
motFIN	0.10	0.19	0.17	-0.22	-0.07	-0.05	-0.01	-0.01

Size is only significant, with high marginal effect, in the motivation form, while exports to OECD appear only in the form with actual data with marginal effect equivalent to sanctions. Since our investment proxy is a ratio to total investment and, consequently, already takes into account part of the size component, we could expect such absence in both models. However, that is not the case. One possible explanation that must be considered is that our variable expOECD is related to firms that export more than 10% of their sales and so they must also somehow reflect size level.

5.3 Environmental Operational Control Costs

As specified to investments, environmental operational control costs (EC97) is somehow correlated to past investments insofar as high capital costs require high operational costs. However, in this case, simultaneity has to be also avoided and, therefore, we cannot control for our EMP variable. As in EI97, we will use 1996 investment variable (inv96). Subsidized credit refers to 1996 since the 1997 subsidies are not already captured in the 1997 costs.

As shown in the previous section, our variable of EC97 has a frequency limited to values of zero, and less and above 5% of total operational costs. So our analysis is somehow jeopardized by the fact that we are capturing a significant variation in cost levels. Bearing this in mind, we must be careful about conclusions based on these results.

Again we will apply the two variable sets for vectors **M** and **E**, as follows:

EC97a = f (inv96, [lnemp, intship, green, brown[(X), [fin1996, expOECD, ISO14] (M), [sanction] (E)) (4)

EC97m = f (inv96, [lnemp, intship, green, brown] (X) , [motFIN, motCOST, motEXP, motDEM] (M), [motEPA, motCOM] (E)) (5)

Here we also apply an ordered logit to deal with the three dummies in the dependent variable EC97.

Table 15- Results for the Environmental Operational Cost Ratio (CI97)

	EC97a	EC97a	EC97m	EC97m
lnemp	-0.08		0,43	0,42
	(0.39)		(2.89)***	(2.88)***
intship	0.96	0.77	0.94	1.05
	(2.11)**	(1.89)*	(2.52)**	(2.81)***
envunit	0.71	0.69	0.37	
	(1.48)	(1.67)*	(0.87)	
green	-1.35	-0.98	-1.84	-1.6
	(2.70)***	(2.35)**	(4.61)***	(4.53)***
brown	-0.39		-0.4	
	(1.03)		(1.22)	
fin1996	1.49	1.56		
	(3.25)***	(3.75)***		
expOECD	1.14	1.03		
	(2.63)***	(3.02)***		
ISO14	-0.28			
	(0.74)			
sanction	0.32			
	(0.92)			
motFIN			-2.34	-2.45
			(2.03)**	(2.22)**
motCOST			0.75	0.85
			(2.16)**	(2.52)**
motDEM			-0.78	-0.78
			(1.80)*	(1.82)*
motEPA			0.89	0.99
			(2.40)**	(2.72)***
motCOM			0.71	0.71
			(1.95)*	(1.97)**
motEXP			0.65	
			-1.24	
Observations	171	192	226	227
Prob > chi2	0.00	0.00	0.00	0.00
Pseudo R2	0.12	0.10	0.15	0.14
Log likelihood	-121.75	-143.1	-161.24	-163.54

Robust z-statistics in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 16- Marginal Effects of Environmental Operational Cost Ratio

EC97a				
Variables	**Average Change**	**no cost**	**less than 5%**	**over 5%**
intship	0.08	-0.12	0.07	0.05
envunit	0.07	-0.11	0.07	0.04
green	0.14	0.21	-0.17	-0.04
fin1996	0.14	-0.2	0.07	0.14
expOECD	0.12	-0.18	0.11	0.61
EC97m				
Variables	**Average Change**	**no cost**	**less than 5%**	**over 5%**
lnemp	0.16	-0.08	0.06	0.02
intship	0.11	-0.16	0.10	0.07
green	0.24	0.36	-0.31	-0.05
motFIN	0.36	0.54	-0.51	-0.05
motCOST	0.10	-0.15	0.11	0.04
motDEM	0.11	0.16	-0.13	-0.03
motEPA	0.14	-0.21	0.17	0.04
motCOM	0.08	-0.12	0.08	0.04

Table 15 shows results from the full and final regressions and the respective marginal effects for the final form are shown in Table 16. As can be seen, fitting is not as strong as in the previous regressions, although the motivation form shows a better fitting of 0.14 than the 0.10 in the actual form. Nevertheless, results are quite consistent. As expected, costs have no correlation with sanctions, actual or expected, since those are not supposed to affect operational costs.

Consistency is also found in the sector coefficients that are significant in both forms and showing that cleaner activities in the green sector face lower probability of high costs, although magnitudes are distinct in each model. Foreign ownership also affects cost upward with equivalent marginal effect.

Once more, as appearing in the investment models, while size is only significant in the motivation form, exports are significant only for the form that uses actual data. Large and export firms as well as internationally tied ones may face higher cost levels perhaps because they may be more concerned with properly operating of the abatement devices and other control practices and, consequently, incur in more expenditures to do so.

The same lack of consistency may be found in financing from governmental costs and motivation decrease. One plausible explanation is that motivation to access subsidized credit reflects past behaviour that, in fact, as expected, reduces costs. Opposite to the investment regressions, access to subsidized credit should reduce. However, recent borrowings, even from public credit, increases costs when they actually incur. As can be seen, motivation shows the correct sign with the highest marginal effect whereas 1996 credit (fin1996) inversely increases costs with equally high effect.

Motivations from cost savings and to avoid community pressures with the positive sign are plausible, particularly the former. Surprisingly, as the opposite of the previous results for the index of control practices, actual exports to OECD is significant to control costs rather than motivation to increase export competitiveness. It is also worth to note that motivation to improve the quality of the produced goods appears for the first time in our alternative regression models and yet with negative sign. As said before, we believe that the scope of cost data is somehow limited to our analysis, and these inconsistencies may be related to this.

6. Conclusions

Although our database comes from a survey with very rigorous sample criteria, representing the whole Brazilian industrial sector of medium and large firms, it offered very limited variety and scope of data.

Nevertheless, we have been able to test three proxies of environmental performance indicators as well as to rely on two sets of determinant factors. The former covered three indicators, namely: index of a weighted average number of environmental control practices (EMP) adopted by firms, 1997 ratio of environmental investments to total investments (EI97) and 1997 ratio of environmental operational costs to total operational costs (EC97).

Apart from the firms' characteristics, determinants were either based on actual data or on motivations regarding compliance with regulation and advantages taken from market opportunities resulting from sounder environmental performance. Therefore, we performed two different regression models for each performance indicator. One with actual data (subsidies, exports, certification and sanctions) and other regressing against equivalent facts expressed by motivations reflecting cost savings, competitiveness of exports, improvement of the quality of products, requirements to obtain subsidized credits and demands from regulators and community.

For each indicator we ran two models with each set of determinants. The most consistent results, however, were the indication that sanctions and demands from regulators are the most influential determinants in the adoption of practices. In the case of investments, the actual sanction is significant and motivation to meet EPA's demands is not. This may suggest that the Harrington paradox is also confirmed in Brazil, when firms

build up their environmental control systems with motivations to avoid sanctions. When sanctions actually occur they become an important determinant in the investments, in order, perhaps, to change firms' classification as bad compliers, and avoid high enforcement sanctions.

The motivation to meet demands from local communities and NGOs is also relevant for the adoption of control practices, although with much lower influence than other types of motivations, particularly against the regulator's demands. However, we have not been able to verify whether the community demand is conveyed to firms directly or through regulators and prosecutors. The indirect way seems plausible and has already been confirmed in the state of São Paulo, in Brazil, where the most developed industrial sector is located, in a recent study by Ferraz and Seroa da Motta (2001).

Also consistent result in both models for EMP is that some characteristics of the firm, such as size and origin of capital, influence the firm's environmental behavior. Larger firms tied to foreign groups show higher index of environmental practices, which is to say that they tend to adopt more control practices than others do. This is not a surprise since they are just the ones that have the financial capability to do so.

Another interesting result is on the importance of motivations on cost savings and environmental requirements to access subsidized credit for the adoption of environmental practices. This can indicate that industrial firms in Brazil capture cost-effective environmental control opportunities and that requirements on compliance to access credits are creating incentives to better environmental control performance.

When 1997 investments are considered with actual data on export share to OECD countries and access to governmental credits, both variables show significance and high marginal effects, particularly for credits. Motivations on access to public credit and

improvements on export competitiveness are also significant to explain the adoption of control practices. All these items confirm that market opportunities and governmental support also play a role in current investments.

For 1997 investments, pollution intensity of the industrial activity is determinant in both models when we control for sectors according to these intensities. That is, the cleaner the activity the lower the index of practices and 1997 investment level. The same sectoral trend is observed for environmental operational costs that are also highly influenced by foreign ownership and size in the same way as investments.

Despite the conventional wisdom that enforcement of regulation is weak in Brazil, our results are indicating that industrial environmental management in Brazil is highly affected by the level of sanctions and that there is a clear motivation to avoid sanctions. Based on these findings, regulators may follow strategies that would enhance compliance together with economic efficiency. To carry this on, we recommend:

(i) To stimulate compliance-dependent regimes to allocate restricted budgetary resources that give firms a laxer treatment according to their previous compliance performance, and increase inspection and heavier sanctions to those regarded as bad compliers. In doing so, regulators may maximize their budgets in order to get higher compliance.

(ii) To devise alternative flexible types of sanctions that create a price for pollution and uses of natural resources in order to make it possible for firms to internalize compliance costs according to their own capability, provided the aggregate level of emissions or use is attained ? This could be applied with either environmental taxes or tradable emission or the use of quotas. With these instruments, total compliance

would be attained with lower total costs and, therefore, at higher economic efficiency, apart from generating some level of revenue to be channeled to either reduce other tax payments (as the one on labor, per example) or even increasing budgets for monitoring and enforcement[13].

(iii) To keep options of subsidized credits but in the way that they strengthen ties between access to this credit and compliance status. Nevertheless, it must be noted that subsidies divert resources from other governmental policies and that compliance, as demonstrated before, may be achieved with instruments that are neutral in fiscal terms.

(iv) To increase access to information on cost savings, and demand ecologically driven benefits attained with higher environmental performance and, therefore, reducing transaction costs of implementing procedures aimed at these targets.

(v) To create mechanisms that facilitate local communities to access information about the firms' environmental performance and thereby add complementary efforts on enforcement. This can be done with low-cost initiatives, such as, inventory of pollution release and list of best or worse firms according to specific parameters on compliance status.

Although there will be a temptation to extrapolate these findings and recommendations to countries at the same institutional and economic development levels as Brazil, at least for their most developed regions, we would rather suggest a cautious approach. As said before, findings in the respective literature have found some crucial

[13] See Seroa da Motta, Huber and Ruitenbeek (1999) for a detailed analysis of these market-based instruments in environmental management in Latin America and the Caribbean.

differences on the role of each determinant in regard to the country where the analysis is done. Threfore, it would be prudent to undertake equivalent research efforts on country-specific basis to verify how the pattern and trend of these determinants behave before policy prescription is recommended.

Even our study is not definitive and further analytical work should be promoted for Brazil in which a more detailed database could allow us to deal with simultaneity and endogeneity problems in modeling issues such as community strategies and regulator's behavior, to assure the application of sounder theoretic and econometric manners.

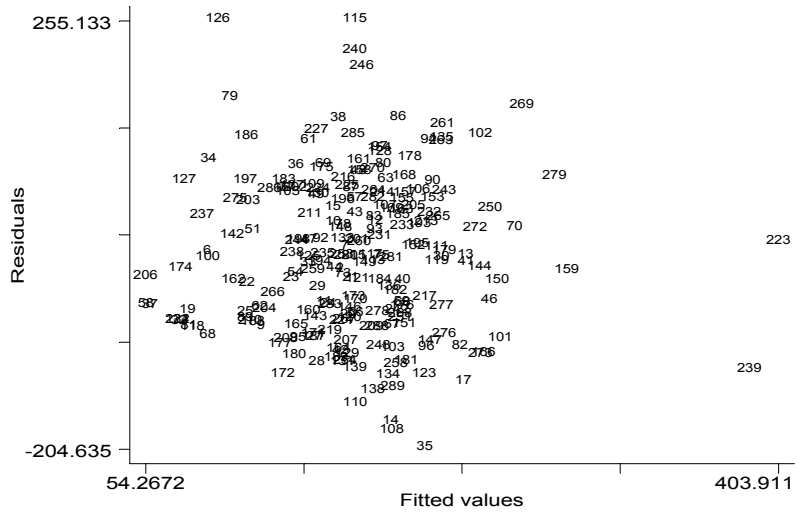
Annex - Analysis of Outliers

Before we undertake an econometric analysis, it is important to detect the presence of observations that diverge substantially from the rest of the sample, i.e., the outliers. They can cause serious impacts on the properties of the regressions.

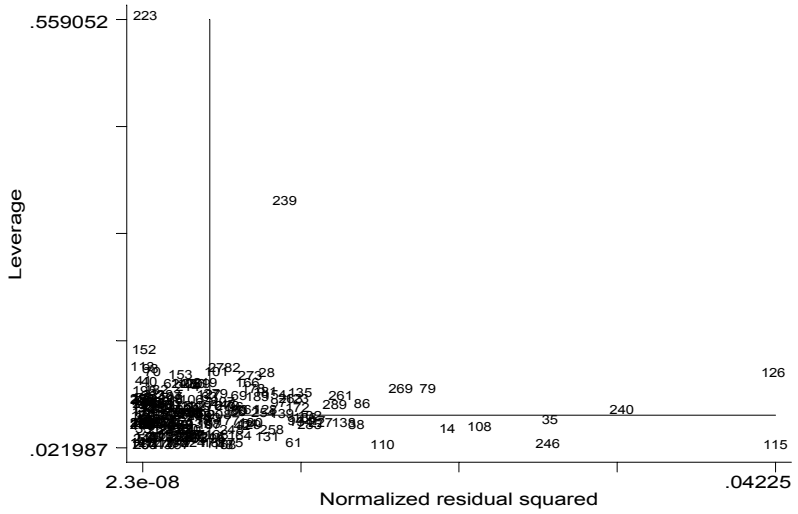
Errors associated with typing and transcription were already accounted for during the process of reporting the survey's results. Here we analyze outlier behavior associated to the fitted values of the indicators and their residuals and distribution and conditional continuous variables.

Graph 11 correlates residuals and fitted values of the indicator of average number of environmental practices (EMPm). As can be seen, the dispersion of residuals is not biased, although observations 223 and 239 present an outlier behavior. Graph 12 relates mean values of this indicator with residuals and the same observations appear on the right side out of the concentration area.

Graph 11 – EMPm Residuals and Fitted Values

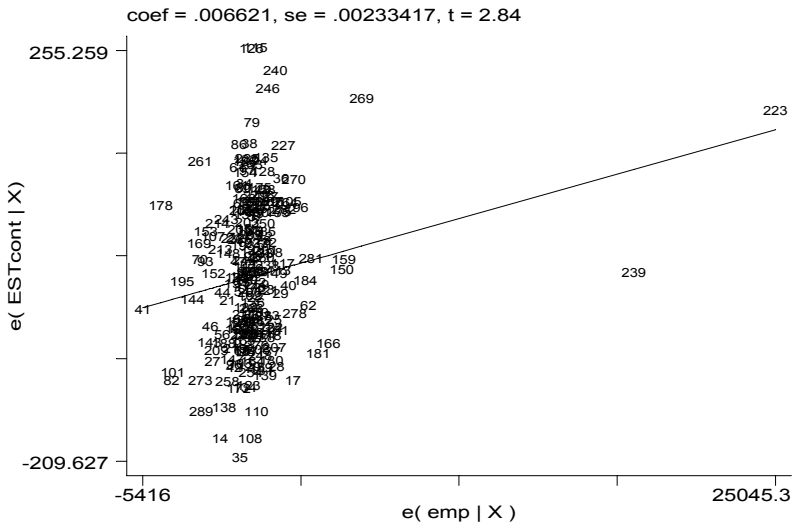


Graph 12 - EMPm Mean Values and Residuals

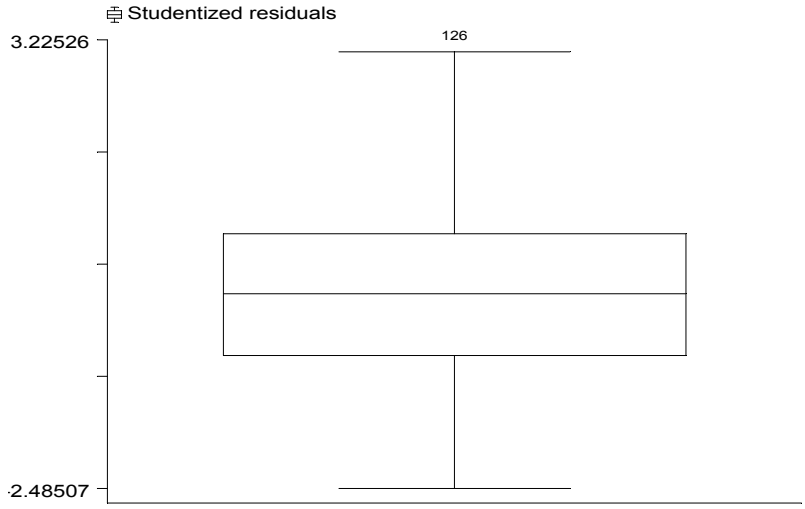


Graph 13 is a partial regression of EMPm conditional to lnemp, and as can be seen, observations 223 and 239 are out of the other outliers. In Graph 14 we have a student distribution of residuals showing that observation 126 is an outlier. In sum, observations 126, 223 and 239 were taken out, and the above analysis was repeated showing that outlier behaviors were corrected.

Graph 13 - EMP Fitted Values Conditional to lnemp



Graph 14- EMPm Residual Distributions



We applied the same analytical procedures to EMPa, which indicated the same outliers. For environmental investments (EI97) and operational costs (EC97) we found no outlier behavior.

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