Increasing Compliance with Emissions Standards in a Less Developed Country

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Abstract

This paper analyzes the effectiveness of the Industrial Pollution Reduction Plan undertaken by the municipal government of Montevideo, Uruguay to increase the levels of compliance of industrial firms with effluent standards. The estimation results indicate that the Plan failed to increase the levels of compliance. Even more, the enforcement activity by the municipal and national governments had no statistically significant marginal effect on the level of BOD_5 reported by the plants. Finally, more than one third of the industrial plants may have under-reported emissions levels, on average.

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1. INTRODUCTION

In 1996 the Municipal Government of Montevideo, the capital city of Uruguay, undertook the third stage of the Urban Sanitation Plan in order to extend the sewage system of the city. An Inter American Development Bank (IADB) loan (948/OC-UR) financed the works. As part of the conditions to access this credit, Uruguayan authorities had to commit to increase the compliance levels of the city industries with emission standards (Multiservice *et al.*, 2001).[1] With this objective, the municipal government implemented the "Industrial Pollution Reduction Plan" on March 1st 1997. [2] This paper analyzes the effectiveness of this Plan.

Most of the existing literature on the empirical analysis of the enforcement of industrial environmental regulations refers to developed countries. More specifically, the US and Quebec pulp and paper industry and the US steel industry [see Magat and Viscusi, 1990; Deily and Gray, 1991; Gray and Deily, 1995; Laplante and Rilstone, 1996; Nadeau, 1997; Helland, 1998; Dion *et al.,* 1998; Gray and Shadbegian, 2002 and Shimshack and Ward, 2005). Nevertheless, while several authors have acknowledged the lack of institutional capacity in less developed countries to enforce environmental regulations (see Eskeland and Jimenez, 1992; Tietenberg, 1996; Russell and Powell, 1996, O'Connor, 1998; Blackman, and Harrington, 2000), there are few empirical studies analyzing the effectiveness of environmental regulators' enforcement activity in less developed countries. A possibly important reason that may explain this gap in the literature is data availability. For example, Palacios and Chavez (2005) analyze the determinants of compliance in the Emissions Compensation Program of Santiago, Chile, but they were not able to obtain information on inspections or other enforcement actions of regulators on industrial plants. Similarly, Dasgupta, et al. (2000) and Gangadharan (2005) use data collected on a survey conducted by the World Bank to analyze the determinants of compliance in Mexican industry, but the data does not include information on the number of inspections or other enforcement data performed on these plants. It does not include also data on emissions, but a qualitatively index of self-assessed compliance with environmental regulations defined in general. Finally, Dasgupta *et al.* (2001) and Wang and Wheeler (2005) study the impact of inspections and pollution charges on industrial plants emissions levels in China with plant level data. Dasgupta, et al. (2001) were able to test the positive deterrent effect of this system of pollution control on emissions in Zhenjiang. Wang and Wheeler (2005) use cross-section data of Chinese industries and regulators to study the joint determination of the pollution levy and the emissions level. Both of these studies provide the first insights into the effectiveness of a pollution control system based on an effluent charge in a less developed country-context. Nevertheless, command-and-control instruments continue to be the general approach to pollution control in these countries in general, and in Latin America in particular (CEPAL, 2000). Moreover, it is commonly said that environmental regulation in the region is poorly enforced but there is no rigorous empirical analysis providing evidence about the severity of the problem and that may help to draw conclusions on possible effective strategies to improve compliance levels. This paper helps to start filling this gap in the literature by studying regulators effectiveness in the enforcement of industry emissions standards in Montevideo, Uruguay. In order to do this, I use detailed time - series, plant – level data of emissions *and* inspections, intermediate enforcement actions and fines.

In order to fulfill this objective, in a first step I estimate probabilities of inspections of both the municipal and national governments that I use to estimate, in a second step, the effect of the enforcement

[1] In July 1997, first month in my sample period, 76% of the levels of BOD_5 reported by the firms were above the emissions standards.

[2] Resolución Municipal Nº 761/96, Plan de Reducción de la Contaminación de Origen Industrial, February 26th, 1996.

actions and the Plan itself on the level of BOD_5 and the violation rate, respectively. I also provide some simple tests for under-reporting.[3]

2. INDUSTRIAL EFFLUENTS CONTROL IN MONTEVIDEO, URUGUAY

Industrial effluents in Uruguay are regulated by uniform emission standards.[4] These standards are defined in terms of concentrations of pollutants in discharges. Industrial plants that discharge directly to water bodies face stricter standards than those that discharge to the sewage system.

Both the Municipal Government of Montevideo (hereafter MUN) and the national Ministry of the Environment (hereafter NAT) have jurisdiction over industrial water pollution control in the city. In theory, the MUN is responsible for monitoring and enforcing emissions standards, while the NAT grants the Industrial Discharge Authorization when it determines that a firm has a treatment plant that enables it to comply with the emission standards. In other words, the NAT is in charge of "initial compliance", while the MUN is in charge of "continuous compliance". This institutional organization is the result of an informal agreement between the NAT and the MUN that took place in 1995. In this agreement the NAT let the monitoring and enforcement of industrial effluents in Montevideo rest in the hands of the municipal government, while concentrating its own enforcement efforts in the rest of the country. The NAT would continue to be the office in charge of granting the emissions permits countrywide, including Montevideo. But while the division of responsibilities was clear in theory, coordination between the two offices remained poor in practice. First, the NAT continued to perform inspections in the city industrial plants to assess compliance to emissions standards, even after initial compliance was verified. Second, BOD_5 and Chromium emissions standards for wool washing firms and tanneries established by the MUN as part of the Industrial Pollution Reduction Plan were indefinitely set at levels higher than the standards set by NAT. In other words, the municipal Industrial Pollution Reduction Plan relaxed the emissions standards of BOD_5 and Chromium for these two types of plants indefinitely. According to conversations with NAT inspectors, this inconsistency generate problems because firms argue that they are complying with municipal standards while the NAT requires them to meet emission standards set by the national decree.

The NAT's Division of Environmental Control is composed of only five persons. These five persons are not only in charge of monitoring and enforcing water pollution legislation, but also the rest of the national environmental regulations. Staffing is a bit better at the Industrial Effluents Unit of the MUN, where seven persons work, but they are only in charge of industrial emissions in Montevideo. These constraints motivated the mentioned agreement, aimed at saving scarce monitoring and enforcement resources.

The problem of low institutional capacity may be compounded by the unwillingness of some regulators to impose the costs of environmental compliance on firms. Apart from the Plan itself, which was born to give the firms time to increase their levels of compliance with emission standards given the "present reality of the industry", an important MUN official stated in an interview that although he was working at an environmental protection office, he was not willing to sacrifice Uruguayan industrial production by imposing environmental compliance costs on industrial plants that have an important role as job creators in a very depressed national labor market. The severe economic crisis that started in 1999 may have deepened this view. The MUN imposed only eleven fines and the NAT only five between May 1997 and October 2001. During this period the reported violation rate remained above 40%. The Industrial Pollution Reduction Plan ended in 1999, therefore the grace period implemented by the Plan cannot be the only reason for this particularly low number of fines.

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[3] What I refer to as BOD_5 is more specifically $BOD_{5,\,20}$. This is the quantity of oxygen required by aerobic microorganisms to decompose organic matter in a water sample during five days at a water temperature of 20^o Celsius in the dark. It is used as an indirect measure of the total organic matter in the water sample and therefore serves as a measure of organic water pollution.

[4] Decreto 253/79, "Normas para Prevenir la Contaminación de las Aguas"

3. DATA

3.1 Information Sources

Every four months, the plants report to the Industrial Effluents Unit of the municipal government monthly levels of (1) production, (2) water consumed, (3) energy consumed, (4) number of employees and days worked, and (5) volume of emissions and concentrations of pollutants. From all the pollutants reported I chose BOD_5 because organic water pollution is one of the most important in the city and it is one that every plant has to report, regardless of its branch. It is also one of the two pollutants targeted by the MUN, in accordance with the IADB, together with Chromium.

At the same time, regulators conduct inspections to assess compliance. Two types of regular inspections exist: (a) sampling inspections, consisting of samples taken from the treatment plant's effluent, and also an evaluation of both the plant's performance and overall economic condition, and (b) non-sampling inspections, consisting of everything in (a) except effluent samples.[5]

I use three sources of data. From the MUN, I obtained information on items (1) to (5) above, and on inspections and fines. The information on inspections consists of the number of sampling and non-sampling inspections performed by the MUN per month per plant. Samples are measured in mg/l of BOD_5. The information on fines consists of the number and amount of fines levied by the MUN on each industrial plant per month. The sample period for inspections is July 1996 – October 2001. The sample period for fines is May 1997 – October 2001.

The second source of information is NAT. It provides the same type of information on inspections and fines, plus the total number of compliance orders (a note communicating a potential fine) issued by NAT. The sample period for all NAT variables is July 1996 – October 2001.

The third source of information is the private consulting partnership SEINCO, in charge of the Monitoring Program that the MUN implemented between April 1999 and September 2001. Information from this source consists of the number and result of sampling inspections conducted by SEINCO during this period.

Overall, the data set includes 74 privately owned industrial plants in Montevideo.[6] These plants are responsible for more than 90% of the total industrial organic pollution in the city. Nevertheless, these 74 plants are not all the private industrial plants in the city, but those which the MUN consider more relevant in terms of pollution load and therefore keeps record of.

Table 1 presents the descriptive statistics for the reported input and pollution variables.[7] There are a couple of things to notice from Table 1. First, the mean value of mg/l of BOD_5 in effluents is larger than the emission standard. These are: 60 mg/l for plants emitting directly into a water body, and 700 mg/l for plants emitting into the city sewage system. The median is 370 mg/l, almost 1/3 of the mean. This indicates that the distribution of emissions in the sample is skewed, with some plants driving the mean upward. The same can be said for most of the variables in Table 1. Second, all variables have missing values. I refer to this problem in the next section.

Table 1 here

Table 2 here

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[5] Possible reasons for not sampling are that a plant may not be working or discharging at the time of inspection. This poses a problem for national inspectors, who have rigid schedules in Montevideo because they must also inspect firms in the rest of the country.

[6] Publicly owned industrial plants did not report emissions during the period.

[7] Descriptive statistics for levels of production are not presented for space reasons.

Table 2 shows the descriptive statistics for the monitoring and enforcement variables. The information is presented separately for the MUN, the NAT and SEINCO. The first thing to notice in Table 2 is that the NAT inspected fewer plants than the MUN: 61 plants the NAT vs. 74 the MUN. The MUN inspections were quite often. According to the frequency of inspections in this period, a plant had an 11.6% chance of being inspected by the MUN in a given month. Unluckily, the MUN did not have comprehensive data on compliance orders, postponements and fine threats, as the NAT did. "Compliance orders" are letters of warning sent to firms when a violation is discovered indicating that it has a period of time to correct the situation (usually a treatment plant operation failure) or it may be fined. "Postponements" are communications to firms giving them more time than the one originally given in the compliance order. "Fine threats" are notes sent to firms as a second warning, after the compliance order. Table 2 also shows that the MUN imposed eleven fines during the months of July 1997 and October 2001, while the NAT imposed 4. The fines imposed by the NAT were larger, though, as measured by October 2001 US dollars.

Finally, the descriptive statistics for reported violations are presented in Table 3. Two variables were constructed. First, "Reported Extent of Violation", defined as reported emissions of BOD_5 (mg/l) minus the concentration standard, censored at zero; i.e., over-compliance results in a value of zero. Table 3 also includes descriptive statistics for "Compliance Status", a variable equal to one if the plant reported a violation and zero otherwise. The calculations are done using the original standards during the entire period and also using the laxer standards of the Industrial Reduction Plan during July 1997 – December 1999.

Table 3 here

Reported violations were frequent, even when measured as emissions in excess of the laxer Plan´s standards. Forty-one percent of the reported BOD_5 levels were out of compliance with these emission standards. The number of reported violations as a percentage of the number of reports never decreased below 25% in a given month in the case of the Plan's laxer standards and 41% in terms of the original standard. The mean extent of a violation was large (338.8 mg/l), although the median was zero. Again, the data says that some heavy polluters drive the mean of emissions and extent of the violations up.

3.2 Missing Values

Missing values accounted for 14.0% of possible observations. The values were missing either because a plant did not report during a given period (a "unit" non-report) or because the report had missing values for one or a subset of variables (an "item" non-report). There were a total of 62 unit non-reports over a total of 962 possible reports (74 plant times 13 four-month reporting periods). Six correspond to four plants that ceased production. Twelve correspond to reported "no-activity" periods of three different plants.[8] Sixteen correspond to three plants that started business during the period. The remaining 28 correspond to "random" non-reports.

I cannot perform Verbeek and Nijman's [39] test for "ignorability" because I have zero observations for a "balanced" sub-panel; i.e., I have no month in which all 74 plants reported. Nevertheless, it could be said that the process generating the missing values (in the cases of unit non-reports) could be "non-ignorable", since it is, among other things, related to the level of production, as explained above.

I imputed values for item non-responses prior to estimation. These account for 61.1% of the total missing observations. The literature proposes several methods for imputing missing values. (See [27] and

[8] I treated these as missing because sometimes firms sent letters to the MUN indicating that they were producing "very low" quantities and therefore it was not worth reporting emissions. In one case a letter was followed by three non-reports in the following periods without any clear information regarding exactly when production started again.

Little (1992) [26]). I used an iterative Buck (1960) [5] procedure for each plant, as suggested by Beale and Little (1975).[9]

4. SPECIFICATION AND ESTIMATION ISSUES

4.1 The Inspection Equations

Because it is not clear a-priori if regulators coordinated monitoring efforts or shared information on a regular basis about the result of their inspections, I estimate separate inspection equations for the MUN, the NAT and SEINCO. For each of the three agencies, the inspection equations are estimated to provide probabilities of inspection for the reported BOD_5 and violation equations.

Performing a Hausman specification test for plant-specific fixed effects, I reject the null hypothesis of a common intercept in the three cases. Therefore, I estimate a plant-specific fixed-effects model using the procedure suggested by Chamberlain (1980), as cited in Greene (1997). The model itself is referred to as conditional logit.[10] In the procedure, however, fixed-effects are swept out or removed during estimation. This creates a problem because I need intercepts` estimates to obtain predictions for the probabilities of inspection. To overcome this problem, I use a logit model with no fixed effects (i.e., a model with a common intercept) to obtain the fitted probabilities of inspection. (Its results are not reported). I refer to this as unconditional logit.

The municipal government (conditional logit) inspection equation is:

$$PMUN_{i,t} = \gamma_i + \gamma_1 \mathrm{E}_{i,t} + \gamma_2 \mathrm{Z}_{i,t} + \gamma_3 VOL_t + \Gamma_t + \eta_{i,t} \qquad (1)$$

where $PMUN_{i,t}$ is defined as the probability of being inspected by the MUN, $\mathrm{E}_{i,t}$ is a vector of inspections and enforcement actions taken by the MUN, the NAT and SEINCO in the last twelve months, $\mathrm{Z}_{i,t}$ is a vector of other covariates, such as the number of times the plant did not report in the previous two reporting periods and whether the plant emitted to a stream or the city sewage system. I also included the monthly level of the industrial production index (VOL_t), a measure of the industry production activity calculated by the National Institute of Statistics, to account for the possible effect that the economic crisis might have had on inspections. Γ_t is a vector of three dummy variables. Two are included to capture the effect of the Industrial Pollution Reduction Plan implemented from March 1997 to December 1999. I included two dummy variables instead of only one to differentiate between the months of the Plan where SEINCO was inspecting from those where it was not. During these months the MUN inspectors conducted special IADB-financed monitoring campaigns due to the delay in the implementation of the Monitoring Program. The third dummy variable is due to a special monitoring campaign performed during 1999 by the NAT on plants in one of the streams of the city (Carrasco Stream). While I expect this variable to be more important in the NAT equation, I include it in the MUN equation to keep the specifications comparable. Finally, γ_i is a plant-specific fixed effect, and $\eta_{i,t}$ is an error term, assumed to be identically and independently distributed with zero mean and to have a logistic distribution.[11] The plant-specific fixed effects are replaced by a common intercept in the unconditional logit specification.

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[9] A document describing the distribution of missing values per variable by industrial plant, the processes followed to impute for item non-responses in each plant, and the corresponding iteration procedures is available from the author upon request.

[10] "The probit model does not lend itself well to the **fixed effects** treatment…There is no feasible way to remove the heterogeneity, and with large number of cross-sectional units, the estimation of the $\alpha_i's$ (the fixed effects) is intractable. Some progress has been made on a **random effects** specification." (See Greene (1997, p. 897), bolds in the original). "In contrast to the probit model, the logit model does len itself to a *fixed effects* treatment (but not a random effects specification)." See Greene (1997, p. 899), italics in the original).

[11] Complaints by neighbors may be another determinant of inspections. Unfortunately, the MUN did not keep information regarding these complaints.

The variables included in the vector $E_{i,t}$ are, more specifically, the following: the cumulative number of inspections performed on the plant during the past twelve months by the MUN, the NAT and SEINCO.[12] It also includes the number of inspections performed by the MUN on the other plants during the last 12 months. With MUN monitoring activities affected by budget constraints, the sign of this variable's coefficient is expected to be negative, indicating that the higher the number of inspections performed on other plants in the recent past the smaller the probability of inspection on a given plant. Another covariate included in this vector is the cumulative number of fines imposed the plant during the past 12 months.[13]

The Monitoring Program financed by IADB and performed by the consortium SEINCO also affected the MUN frequency of inspection. This is why I also included the cumulative number of inspections performed by SEINCO on a plant in the last 12 months in the vector $E_{i,t}$. To capture the effect of monitoring and enforcement activity of the national government on inspection activity of the municipal authority, I also included the cumulative number of inspections and the cumulative number of compliance orders, fine threats, and fines issued by the NAT during the previous 12 months.

The specification of the NAT and SEINCO inspection equations follow Equation (1).

4.2 The Reported BOD_5 Equation

Equation (2) is a pollution equation in the spirit of Magat and Viscusi (1990), Laplante and Rilstone (1996), and Dasgupta *et al.* (2001).

$$BOD5_{i,t} = \lambda_1 BOD5_{i,t-1} + \lambda_2 A_{i,t} + \lambda_3 DURINGPLAN_t + \lambda_4 X_{i,t} + \mu_i + \nu_{i,t} \quad (2)$$

The parameter μ_i is a plant-specific effect. (A Chow test rejected the null hypothesis of common constant term). The dependent variable, BOD_5, is the logarithm of the level of organic pollution reported by plant *i* in month *t,* measured in mg/l.[14] This variable is expressed as a function of two sets of variables, one reflecting the marginal benefits and the other the marginal expected costs of pollution. Marginal benefits of pollution are represented by the log of the price index of the final good and the log of the quantities of inputs used (labor, energy and water). These variables are included in the vector $X_{i,t}$, together with the value of exports (in US$) in the last six months. The idea behind including this last variable was to capture if exporting plants pollute less due to foreign markets demand for lower levels of pollution.

Marginal expected costs are represented by monitoring and enforcement variables (vector $A_{i,t}$). These consist of the probabilities of being inspected and the number of inspections performed on the plant the last twelve months by the municipal and the national governments. The probabilities of being inspected are obtained fitting the unconditional logit inspection equations. They are intended to capture the effect of future possible enforcement actions due to today's pollution decisions. They are also acting as instruments for actual inspections. Provided that there is no contemporaneous correlation between the error term in the pollution equation and the error terms in the inspection equations, these fitted values will be uncorrelated with $\nu_{i,t}$, and least squares will yield consistent estimates of the parameters in the pollution equation. I allow the marginal impacts of the probabilities of inspection on reported pollution levels to vary during and after the Pollution Reduction Plan including interaction effects between these variables and the dummy variable $DURINGPLAN_t$. This variable measures the success of the plan.

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[12] I tried the cumulative number of inspections performed in the last six months instead of 12 months. The two models produce very similar results, but six-month lagged inspections were not statistically significant. The twelve-month lagged inspections were statistically significant and increased the goodness of fit of the model.

[13] The inclusion of the cumulative number of detected violations instead of fines did not improve the fit of the model. Also, the cumulative amount instead of the cumulative number of fines did not change the results.

[14] The reason for estimating a reported BOD_5 equation, with the dependent variable in mg/l, is that emission standards are defined in terms of mg/l.

Because current pollution could be the result of past monitoring and enforcement actions, the vector $A_{i,t}$ also includes the number of inspections by the MUN and the NAT, the number of times fined by the MUN, and the number of warnings and fines issued by the NAT in the last twelve months.[15]

The panel structure $v_{i,t}$ of the errors can exhibit: (1) panel heteroscedasticity, (2) contemporaneous correlation and (3) common or (4) plant-specific serial correlation. I addressed panel heteroscedasticity with three different tests: Bartlett, Levene, and Brown-Forsythe. All suggested rejecting the null hypothesis of panel homoscedasticity in favor of the alternative that not all plant-specific errors' variances are the same. No contemporaneous correlation of the errors is assumed because of the unbalanced nature of the panel, which greatly diminishes the number of observations to calculate the covariances. Also, given the number of observations within cross-sections, the covariances estimates would be inconsistent. A Durbin-Watson test on the residuals of the original regression suggested rejecting the null hypothesis of no autocorrelation in favor of the alternative of first-order autocorrelation. A Chow test was used to test for plant-specific versus common autocorrelation of the errors. Test results indicated that the null hypothesis of common autocorrelation should be rejected in favor of the alternative hypothesis of plant-specific autocorrelation. Given this result, I opted to incorporate a lagged value of the dependent variable. The inclusion of a lagged dependent variable effectively eliminated the serial correlation of the errors.

Finally, our panel falls into the category of panels with a "two-sided small sample". The problem with this type of panels (i.e.: T not short and N not large) is that the common methods to estimate dynamic panels (Anderson and Hsiao, Arellano and Bond, Blundell and Bond) are biased (Kiviet, 1995; Judson and Owen, 1999; Kiviet and Bun, 2001; Galiani and González – Rosada, 2005; and Bruno (2005)). Bootstrapping is also recommended since none of the usual methods (including fixed effects) provide accurate estimates of the standard errors in these cases. Therefore I run a corrected version of the fixed effects model and bootstrapped the errors, both in Stata, using the "xtlsdvc" command recently developed by Bruno (2005) for unbalanced panels. I used Anderson and Hsiao as the first step estimator, as suggested by Kiviet (1995).

4.3 The Reported Violation Equation

In order to test the effectiveness of regulators regarding the reported compliance status of plants, I estimated a conditional fixed-effects logistic model with the dummy $VIOL_{i,t}$ equal to one if the plant reported a violation of the BOD_5 standards as a dependent variable. The specification of this violation equation is exactly the same as the specification of the BOD_5 equation, just discussed. Reported violations were defined with respect to the laxer standards during the Pollution Reduction Plan.

5. RESULTS

Before presenting the results of these equations, in the next section I present the results of some simple tests I conducted to see if the plants under-report their BOD_5. Then I discuss the results of the inspection equations estimated for the MUN, NAT and SEINCO. Finally, I present the results of the BOD_5 and Violation equations.

[15] Monetary fines were not the only penalty levied for not complying. Plants could also be temporarily closed. But neither the municipal nor the national government had trustworthy records of these measures and they were as uncommon as fines during the period. Another form of penalty was to make professionals in charge of treatment plants legally responsible for sending false reports. The objective was to deter professionals from falsifying information and to act on reluctant plants through them. Because high fines are rarely levied in less-developed countries where firms suffer from important cash flow constraints, these alternative penalties may be easier to apply because they do not imply a cash payment. Unfortunately, it was impossible to measure their effects. Finally, the cumulative number of past inspections by SEINCO was originally included in this model but it was dropped due to its correlation of 0.91 with $PINSPSEINCO_{i,t}$.

5.1 UNDER-REPORTING

In spite of having the information, I do not compare BOD_5 reported levels by the plants with the levels obtained by the three inspecting institutions in their sampling inspections. The reason is that if plants are behaving strategically, they are going to report more when inspected. Moreover, plants in Uruguay take a control sample at the time of a sampling inspection. Given that sampling is costly, it is very possible that the results obtained in this control sample are the same that the plants report later to the MUN.[16]

The chosen way to explore for under-reporting is simply to present descriptive statistics of the difference-of-means and standard deviations of the BOD_5 reported levels when inspected and when not inspected (sampled or not), on a plant-by-plant basis. I opted to do this instead of formal statistical tests because the relatively low number of months in which the plants were inspected undermines the power of the tests.

Twenty-eight plants out the sixty-nine in the sample (41%) presented larger average levels of reported BOD_5 when inspected as compared to when not inspected by the MUN. The figure is 34% for the NAT, who inspected fifty-six plants and 33% for SEINCO, who inspected sixty-seven. The plants with larger average reported levels of BOD_5 when inspected by the MUN are also the plants with larger levels for the case of NAT and SEINCO, mostly. For the case of the MUN, the average difference between reported levels of pollution when not inspected and when inspected for plants that "under-reported" on average was 33% and the standard deviation was 26%. In the case of the NAT, the average difference was 75% and its standard deviation 94%, and 38% and 51% for the case of SEINCO. Therefore, I am suspicious that more than one third of the plants seem to be acting strategically (under-reporting). The extent of their under-reporting is not trivial, ranging from one third to three quarters, on average, according to the three inspecting institutions. This result is somewhat new in the literature. Previous papers that did include some type of test for under-reporting did not find evidence of such a strategy. Giving compelling answers about the reason for this disparity is outside the scope of this paper because I have no possibility of controlling for all the possible differences between firms and between Uruguay and the US and Canada (the cases tested). But one possible explanation might be the differences in expected penalties faced by firms in the developed and the less developed world. The issue deserves future research.

Most importantly, the possible presence of under-reporting undermines the empirical analysis of the effectiveness of enforcement measures on emissions. This is why I refer to reported emissions and violations throughout the paper.

5.2 INSPECTION EQUATIONS

In this section I present the estimation results of the conditional (fixed-effects) logistic regressions of the inspection equations for each of the three different monitoring agencies.

5.2.1 MUN Inspection Equation

Results for the MUN inspection equation are presented in Table 4.

Table 4 here

The most important results concerning the inspection strategy followed by the MUN are the following. First, the more inspections a plant received in the past 12 months, the lower is the probability

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[16] This control sample is not mandatory in Uruguay, as it is in Canada, for example. Laplante and Rilstone (1996) compare the levels reported in the months in which the plants were inspected with the levels of the control sample. Therefore, plants in Canada apparently do not report the control sample as they possibly do in Uruguay.

of being inspected again in a given month. This may reflect a sort of sample-without-replacement inspection strategy mentioned by inspectors in interviews. At the same time, the negative effect of the number of inspections performed on the rest of the plants on the probability of being inspected by the MUN on a given month may reflect budget constraints.

Second, the MUN seems to have used SEINCO inspections as a substitute for their own. In effect, according to the estimation results in Table 4, the MUN inspection activity seems to have decreased during the period when SEINCO was inspecting, and increased again after the end of the Plan. Another interesting result is that, according to the coefficient of the industrial production index, the MUN inspectors did not react to the economic situation of the industrial sector decreasing the inspection activity. This result may be explained because the MUN kept to the schedule of activities derived from the IADB loan in spite of the economic situation of the firms.

5.2.2 NAT Inspection Equation

Results for the NAT inspection equation are presented in Table 5. After controlling for the special monitoring campaigns that took place in 1999 on the Carrasco stream, I find that the larger the number of inspections performed by the NAT on a given plant in the last twelve months, the lower is the probability of being inspected in a given month. The same is true with the number of inspections performed on the rest of the plants. Explanations of these negative signs are similar to those given in the MUN case.

Table 5 here

One expects a coordinated activity between a municipal and a national government trying to enforce the same emission standards, so as to observe a negative sign in coefficient estimate of the cumulative number of inspections of one office on the chance of being inspected by the other office. But on the contrary I observe a close to zero and insignificant effect of the NAT activity on the probability of being inspected by the MUN and a positive and almost statistically insignificant effect of the MUN inspections on the probability of being inspected by the NAT. Furthermore, another interesting result is the way the NAT seems to have reacted markedly to the activities related to the Monitoring Program and the Industrial Pollution Reduction Plan implemented by the MUN. First, it increased its monitoring frequency during the MUN Plan in a fashion that is only comparable to the way it increased inspections during its own campaign in the Carrasco stream. Second, it seems to have followed SEINCO activity somewhat, according to the estimated effect of past SEINCO inspections.

Finally, the national government inspectors did react to the economic situation of the firms according to the significant and positive effect of the industrial production index. A possible interpretation for the difference between the MUN and the NAT in this respect is that the national government did not have a commitment with the Inter American Development Bank regarding industrial pollution, unlike the municipal government. Therefore, it could simply inspect less during recessions, as it seems to have done.

5.2.3 SEINCO Inspection Equation

Results for the SEINCO inspection equation are presented in Table 6. SEINCO inspections were very systematic. SEINCO did not take into account recent inspections of the MUN or the NAT to decide who and when to inspect. The only variables that explain SEINCO inspections are past SEINCO inspections, in a sampling without replacement fashion. The timing of SEINCO inspections explains the signs of the coefficients of the industrial production index and the DURINGPLAN dummy.

Table 6 here

5.3 THE POLLUTION EQUATIONS

As explained earlier, I fit the three unconditional models of inspection to obtain probabilities of being inspected by each of the three inspecting institutions, and use these probabilities as explanatory variables in the pollution equations.

5.3.1 The BOD_5 Equation

Results for the BOD_5 equation are presented in Table 7.

Table 7 here

The first thing that strikes from the results in Table 7 is that none of the monitoring and enforcement variables of any of the enforcement institutions have a clear statistically significant effect on the plants' reported level of BOD_5. This result is somewhat surprising and different from previous empirical works, which find a negative effect (as expected) of enforcement actions on the levels of pollution. What account for this difference? It is outside the scope of this paper to give a compelling answer to this question. But comparing descriptive statistics with the US case (taken from Shimshack and Ward [37]) might help to give at least some idea. The average inspection rate in the US was 12% per plant per month. This rate is similar to that of the Uruguayan municipal authorities (11%, although this is not true for the national authorities: 5%). Nevertheless, with a mean violation rate of 41% in Uruguay during the study period the number of fines applied by the Uruguayan authorities was 15, while with a violation rate of 11% in the US, authorities applied 24 fines. Furthermore, the average fine set by the US authorities was $48,000, while it was $1,400 for the MUN and $3,300 for the NAT. Maximum fines were, respectively $600,000, $3,000 and $4,500. What are these numbers telling? There are basically two answers to the puzzle of low compliance rates of environmental regulations in a less developed country and a high compliance rate in a developed country: lack of institutional capacity in the less developed country, or lack of political will. Both are very difficult variables to measure. One of the things in which the lack of institutional capacity may express itself is in the lack of an adequate budget in environmental offices. This seems not to be the case in the municipal government of Montevideo, as explained earlier and as told by the frequency of inspections. As just described, plants in Montevideo face a similar probability of being inspected than industrial plants in the US. Nevertheless, the violation rate Uruguay is much larger than in the US, while fines are rare and relatively small. Although imposing penalties also consumes resources and this may be lacking in less developing countries, this difference in the number and size of penalties may also be the consequence of the lack of political will to impose them. This may be true even after considering that during the soft-enforcement period represented by the industrial pollution reduction Plan.

In any case, the monitoring and enforcement activities seem to have had no statistically significant effect on the reported level of pollution and in that respect they failed as a direct mechanism of enforcing compliance. Nevertheless, monitoring and enforcement activities may have been more effective as indirect mechanisms. According to the sign of the coefficient estimate of the DURINGPLAN dummy, reported pollution was larger during the plan than after the Plan. This result may tell that the Plan was successful in decreasing emissions in some way. The explanation given by MUN inspectors is that the Plan gave them an opportunity to convince industry managers to recruit professionals to be in charge of their treatment plants and to act on the incentives of these professionals at their work. This translated into changes in the abatement and production processes that had an effect on pollution levels. This may be true. Given that the starting situation was bad, even small, easily implementable corrections in the operation of the treatment plants may have had an effect on pollution levels without investing in treatment technology (only eight plants adopted abatement technology during the period). Nevertheless, with the type of information at hand I am unable to disentangle the real reason behind the negative sign of the DURINGPLAN dummy coefficient estimate. For example, a similar result would be obtained if an undetected increase in under-reporting occurred after the plan.[17] Another possibility is that plants may have polluted more during the Plan to take advantage of the laxer standards.

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[17] On average, using MUN and SEINCO inspections, after the Plan ended the number of plants reported more when inspected increased from 1/3 to 1/2, but the average "lie" and its standard deviation decreased. Using NAT inspections the percentage number of plants apparently under-reporting slightly decreased.

Another interesting result is the negative sign of the coefficient estimate of the variable WATER. As noted earlier, water is an important input in pollution abatement because emission standards are set in concentration terms. Therefore, although explicitly prohibited by law, diluting is an easy and cheap compliance strategy and at the same time very difficult to detect.

Finally, the dollar value of exports does not have any explanatory power on the level of emissions. It is very probable that what lies behind this result (contradicting the usual story) is that I do not disaggregate exports by destination. Almost half of the Uruguayan international trade was with Brazil and Argentina during the sample period; two countries with few environmental concerns, and certainly not comparable with those of the developed world.

5.3.2 The Violation Equation

In this section the objective is to answer the question "Do enforcement actions affect the probability of a violation?" To this end, I define the dependent variable as a dummy equal to one if the plant reported a violation. A violation is defined with respect to the laxer standards during the Pollution Reduction Plan. Results are presented in Table 8. This model discards 480 observations belonging to 15 plants that either complied or did not comply in every month and therefore did not add any likelihood to the conditional model. Twelve of these fifteen plants were plants that reported compliance during every month they informed. The rest reported violation. Five of these 15 plants were plants that have larger average levels of reported BOD_5 when inspected in comparison with their reports when not inspected. This figure is similar to that of the whole sample. Therefore, under-reporting is not a bigger problem in this equation relative to the BOD_5 equation.

The most important results obtained are the following. The Industrial Pollution Reduction Plan dummy has a statistically insignificant negative coefficient, indicating that the Plan, whose objective was precisely to increase compliance, did not have an effect on the probability of violation.

Table 8 here

Only the threat of an inspection by the national government has a statistically significant and strong effect on the reported violation status of plants. The effect seems to have been negative during the Plan, but positive and equally important after the Plan ended. Nevertheless, past inspections of both the MUN and the NAT seems to have decreased the probability of a reported violation. Both are not statistically significant at 15%, but their significance levels are smaller than the remaining enforcement variable. Interestingly, and puzzlingly, intermediate enforcement actions and fines have neither a statistically significant nor an important effect on reported status of compliance. Hence, there may be some enduring effect of the activity of inspectors not captured by subsequent enforcement actions. During inspections, form example, inspectors may point easy-to-correct problems to the plants' managers that may result in compliance improvement.

As was the case in the BOD_5 equation, the lagged dependent variable is very statistically significant and its coefficient estimate is one of the largest. With plant specific fixed effects included in the equation this variable may be capturing the fact that plants may not be technologically equipped to change their compliance status from one month to the other. I do not have information on the number of industrial plants with proper effluents treatment plants. But according to interviews with inspectors most of them do not have one. This was one of the reasons for implementing the Plan in the first place. Therefore, considering that most of the seventy four plants did not have an effluent treatment plant, or did not have an adequate one, the number of plants that incorporated abatement technology during the period, eight, could not be regarded as a success in this sense either.

Because of the estimation techniques the number of plants used to estimate this violation equation (54) is not the same as the number of plants used to estimate the BOD_5 equation (69). Therefore, the results of both equations are not strictly comparable. Nevertheless, one thing that must be mentioned is that according to the DURINGPLAN dummy coefficient estimate, the Industrial Pollution Reduction Plan implemented by the MUN to increase compliance rates did not accomplish this goal. The simplest explanation for the negative sign of DURINGPLAN is that during the Plan emission standards were laxer than after the Plan. This fact outweighs the fact that emissions were also larger during the Plan. (Recall the positive effect of DURINGPLAN on reported BOD_5 levels). The result is extremely important because an increase in the levels of compliance of industrial firms with effluent standards was the main objective of the program undertaken by the MUN with funds from the Inter American Development Bank. According to this result, the program failed to accomplish this. If this is true, this result may provide some evidence for Russell and Powell's [36] hypothesis that "there is little the outside world can do - even the multilateral aid agencies with their massive resources of money and expertise" if the local environmental authorities lack the will to impose current costs on the industry sector to enforce environmental regulations.

6. CONCLUSIONS

This study analyzes the effectiveness of environmental regulators activity in the capital city of a less developed country (Montevideo, Uruguay). The results are the following: first, more than one third of the industrial plants report larger levels of BOD_5 when inspected as compared to when not inspected, on average. The extent of this under-reporting is not trivial, ranging from one third to three quarters of the levels of pollution found by regulators in inspections.

Another relevant finding regarding the inspection activity of enforcers is that the municipal government did not take into account the past history of the national government inspections to determine which plants to inspect or with what frequency. Nor do I find statistically significant evidence that the NAT took past MUN inspections into account directly. Furthermore, the NAT did follow the MUN inspection activity indirectly. First, it increased its monitoring frequency during the MUN Industrial Pollution Reduction Plan. Second, it seems to have followed SEINCO activity somewhat. These results are important because when enforcement is in charge of both local and national governments, coordination is crucial to increase effectiveness. I find that agencies are not coordinated. The NAT should have concentrated its monitoring resources on the rest of the country during the period when the MUN or SEINCO increased their inspection activity in the capital city of Montevideo in order to use scarce monitoring resources more efficiently. Nevertheless, the opposite was true. The NAT might have reacted as if it were competing for enforcement. This is undesirable because it undermines the cost-effectiveness of the enforcement policy.

As expected, municipal government (MUN) monitoring and enforcement activity was determined by the IADB-loan. The monitoring campaigns developed by the MUN and financed by the Inter American Development Bank during 1997 and 1998 resulted in an important jump in its frequency of inspections. Also, the MUN used the inspections of a private consortium (called SEINCO) as substitutes for their own during the IADB-financed Monitoring Plan. Finally, the MUN started to monitor industrial plants more closely again after the end of the Pollution Reduction Plan. On the other hand, the national government did not have a commitment with the Inter American Development Bank regarding industrial pollution, as did the municipal government, and at the same time it was politically accountable for the performance of the economy. Therefore, it could simply inspect less during months with low industrial activity, as it seems to have done.

With respect to the effectiveness of this enforcement policy, I find no statistically significant marginal effect of any inspecting or other enforcement activity of both the municipal and national governments on the level of BOD_5 reported by plants. This result is somewhat surprising and different from previous empirical works.

Finally, the main objective of the Plan undertaken by the MUN with funds from the Inter American Development Bank was to increase the levels of compliance of industrial firms with effluent standards. Results suggest that the Plan failed to accomplish this in a direct way. This result may provide some evidence for Russell and Powell's [36] hypothesis that "there is little the outside world can do - even the multilateral aid agencies with their massive resources of money and expertise" if the local environmental authorities lack the will to impose current costs on the industry sector to enforce environmental regulations.

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Table 1: Descriptive Statistics for Reported Input and Pollution Variables
Sample July 1997 – October 2001 - Total Observations: 3,848

Variable	Mean	Median	Std. Dev.	Missing Values
BOD_5 (mg/l)	1,031	370	2,334	952
Effluent flow (m^3/day)	203	52	453	1,034
Tap water (m^3/month)	3,848	784	8,271	638
Underground water (m^3/month)	2,793	750	4,873	1,279
Electricity (Kwh/month)	179,409	68,000	278,828	449
Fuel (m^3/month)	34	12	50	862
Days worked (per month)	22	23	4.6	594
Number of employees	122	60	276	342

Note: 3,848 = 52 months times 74 plants

Table 2: Descriptive Statistics for Monitoring and Enforcement Variables

Sample July 1996 – October 2001
(except for Fines levied by the MUN, which is May 1997 – October 2001)

		MUN – 74 plants				NAT – 61 plants			
	Units	Mean	S.D.	Max.	Sum	Mean	S.D.	Max.	Sum
Sample Inspections	#	0.085	0.286	3	401	0.026	0.158	1	122
Result of sample (BOD_5)	(mg/l)	1,582	3,894	49,925	-	1,102	1,720	10,400	-
Non-sample Inspections	#	0.031	0.212	6	148	0.019	0.137	2	89
Total Inspections	#	0.116	0.378	9	549	0.045	0.210	2	211
Inspections (dummy)	0/1	0.106	0.308	1	502	0.044	0.204	1	207
Compliance Orders	#	-	-	-	-	0.024	0.155	2	112
Postponements	#	-	-	-	-	0.013	0.123	2	60
Fine threats	#	-	-	-	-	0.015	0.126	2	72
Fines	#	0.003	0.052	1	11	0.001	0.029	1	4
Fine ($)	$	1,404	1,050	3,000	15,450	3,375	750	4,500	13,500
Sample April 1999 – September 2001		SEINCO – 71 Plants							
Sample Inspections	#	0.180	0.384	1	666				
Results (BOD_5)	(mg/l)	1,184	2,545	38,000	(mg/l)				

Notes: (1) Observations for fines levied by MUN were available from May 1997 (3,996 observations).
(2) Statistics for amount of fines are based on non-zero observations.
(3) Fines are in October 2001 dollars.

Table 3: Descriptive Statistics for Reported Violations

	Reported Extent of Violation (mg/l)		Reported Compliance Status (Violation = 1, Compliance = 0)	
	Original Standards	Plan's Standards	Original Standards	Plan's Standards
Mean	641.5	338.8	0.54	0.41
Median	20.0	0.0	1.0	0.0
Maximum	38,143	17,125	1.0	1.0
Std. Dev.	1906.7	1124.1	0.50	0.49
Observations	2,699	2,192	2,699	2,192

Table 4: MUN Inspection Equation

Conditional (Fixed-effects) Logistic Regression

Dependent Variable: Inspected by the MUN dummy

Variable	Coefficient	Std. Error	
# Insp. by MUN 12 last months on plant	-0.221	0.067	
# Insp. by MUN 12 last months on other plants	-0.023	0.004	
# Fines by MUN 12 last months on plant	1.105	0.362	
# Insp. by SEINCO 12 last months on plant	-0.179	0.040	
# Insp. by NAT 12 last months on plant	0.010	0.067	
# IEA by NAT 12 last months on plant	0.071	0.070	
Industrial Production Index	-0.000	0.008	
DURINGPLAN WITHOUT SEINCO dummy	1.368	0.293	
DURINGPLAN WITH SEINCO dummy	-0.520	0.207	
Reporting Failure dummy	0.474	0.201	
STREAM dummy	1.078	0.768	
CARRASCO Stream 1999 campaign dummy	0.124	0.414	
Number of Observations	3066	Log like.	-829.00
LR statistic (12 df)	119.1	Pseudo R2	0.067
Prob > chi2	0.000		

Notes: Two-tailed. z-distribution used. One plant (42 obs) dropped due to all positive or all negative outcomes.

Table 5: NAT Inspection Equation

Conditional (fixed - effects) Logistic Regression

Dependent Variable: Inspected by the NAT dummy

Variable	Coefficient	Std. Error	
# Insp. by NAT 12 last months on plant	-0.23	0.088	
# Insp. by NAT 12 last months on other plants	-0.05	0.016	
# IEA by NAT 12 last months on plant	-0.01	0.101	
# Insp. by SEINCO 12 last months on plant	0.09	0.060	
# Insp. by MUN 12 last months on plant	0.13	0.088	
# Fines by MUN 12 last months on plant	0.12	0.533	
Industrial Production Index	0.03	0.013	
DURINGPLAN WITHOUT SEINCO dummy	1.25	0.436	
DURINGPLAN WITH SEINCO dummy	2.00	0.380	
Reporting Failure dummy	-0.27	0.380	
STREAM dummy	0.32	0.949	
CARRASCO Basin 1999 campaign dummy	3.14	0.499	
Number of Observations	1974	Log likelihood	-363.27
LR statistic (12 df)	93.59	Pseudo R2	0.1141
Prob > chi2	0.000		

Notes: Two-tailed. z-distribution used. 27 plants (1134 obs.) dropped due to all positive or all negative outcomes.

Table 6: SEINCO Inspection Equation

Conditional (fixed - effects) Logistic Regression

Dependent Variable: Inspected by SEINCO dummy

Variable	Coefficient	Std. Error		
# Insp. by SEINCO 12 last months on plant	-0.285	0.051		
# Insp. by SEINCO 12 last months on other plants	0.007	0.001		
# Insp. by MUN 12 last months on plant	-0.098	0.067		
# Fines by MUN 12 last months on plant	-0.029	0.494		
# Insp. by NAT 12 last months on plant	-0.005	0.072		
# IEA by NAT 12 last months on plant	0.080	0.092		
Industrial Production Index	-0.017	0.009		
DURINGPLAN WITH SEINCO dummy	2.502	0.156		
Reporting Failure dummy	-0.243	0.262		
STREAM dummy	1.711	1.303		
CARRASCO Basin 1999 campaign dummy	0.279	0.394		
Number of Observations	2130		Log likelihood	-872.78
LR statistic (10 df)	433.7		Pseudo R2	0.1990
Prob > chi2	0.000			

Notes: Two-tailed. z-distribution used. Three plants (90 obs.) dropped due to all positive or all negative outcomes.

Table 7: BOD5 Equation

Dependent variable: Log(BOD_5)		
Explanatory Variables	Coefficient	P-value
Log(BOD_5) $_{(t-1)}$	0.31	0.000
DURINGPLAN dummy	0.18	0.069
Prob. Insp. by MUN	0.42	0.574
(Prob. Insp. by MUN)*DURINGPLAN	-0.78	0.320
Prob. Insp. by NAT	-1.17	0.289
(Prob. Insp. by NAT) *DURINGPLAN	0.80	0.448
Prob. Insp. by SEINCO	-0.42	0.145
(Prob. Insp. by SEINCO)*DURINGPLAN	0.38	0.182
# Insp. by MUN 12 last months on plant	-0.02	0.454
# Insp. by NAT 12 last months on plant	0.02	0.428
# Fines by MUN 12 last months on plant	0.04	0.812
# IEA by NAT 12 last months on plant	-0.00	0.978
Log(Price of the final product)	0.06	0.801
Log(LABOR)	0.61	0.000
Log(WATER)	-0.06	0.067
Log(ENERGY)	0.29	0.000
EXPORTS	-1.62E-09	0.771

Table 8: Violation Equation

Dependent variable: Violation dummy

Variable		Coefficient	P-value
Plant violating previous month		1.01	0.00
DURINGPLAN dummy		-0.33	0.44
Prob. Insp. by MUN		0.02	0.99
(Prob. Insp. by MUN)*DURINGPLAN		-0.35	0.91
Prob. Insp. by NAT		5.39	0.16
(Prob. Insp. by NAT) *DURINGPLAN		-10.34	0.01
Prob. Insp. by SEINCO		-0.11	0.92
(Prob. Insp. by SEINCO)*DURINGPLAN		-0.07	0.95
# Insp. by MUN 12 last months on plant		-0.12	0.16
# Insp. by NAT 12 last months on plant		-0.11	0.24
# Fines by MUN 12 last months on plant		-0.19	0.76
# EAs by NAT 12 last months on plant		0.09	0.30
Log(Price of the final product)		-0.28	0.75
Log(LABOR)		0.28	0.16
Log(WATER)		0.10	0.36
Log(ENERGY)		0.53	0.01
EXPORTS		0.00	0.58
Pseudo R^2	0.11	Prob > chi2	0.00
LR chi2	160.15	Log likelihood.	-678.4