Título: Effectiveness of the Enforcement of Industrial Emission Standards in Montevideo, Uruguay

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Abstract

Unfortunately, the empirical literature on the enforcement of industrial emissions standards refer to case studies in the developed world, mostly the U.S. and Canada. There does not exist any example of this type of empirical work for Latin America. In fact, Dasgupta, et al. (2001) and Wang et al. (2002) are the only examples of empirical studies of effects of inspections and fines on pollution levels and the determinants of the monitoring and enforcement activities of regulators, respectively, for a less developed country (China). This constitutes a very important shortcoming because Latin America has a long tradition in water pollution control laws, but both public opinion and papers that have analyzed environmental policy in the region have regarded them as poorly enforced. Furthermore, many resources are being devoted to developing new regulations and instruments, but no effort is being made to assess the effectiveness of the existing ones. This paper contributes to fill this gap by empirically testing the effect of inspections and enforcement actions of the municipal and national governments on industrial plants' emissions of BOD5 in Montevideo, Uruguay. Results suggest that monitoring and enforcement activity by formal regulators did not have an important deterrent effect on reported BOD_5 levels and the compliance status of the industrial plants. However, I find that the larger the threat of being inspected by the municipal government after the end of the Industrial Pollution Reduction Plan, the larger the level of reported BOD_5 by the plant for that month. This result is consistent with some results of the difference of means tests, which suggest the presence of under-reporting. The municipal government inspections were an effective way of discovering unreported violations, but not enough to deter violations. The low number of fines applied by regulators during the period may explain this fact.

1. INTRODUCTION

This paper is motivated by the present lack of formal econometric studies evaluating regulators' effectiveness in enforcing pollution regulations in Latin America, and the determinants of the allocation of enforcement actions among the regulated plants.

Effectively, the empirical literature that deals with these two issues unfortunately refers only to emissions of biological oxygen demand (BOD_5) and total suspended solids by the US and Quebec pulp and paper industry and air pollution from the US steel industry [see (24), (10), (21), (15), (27), (18), (11), (16) and (34)]. In fact, Dasgupta, et al. (2001) and Wang et al. (2002) are the only examples of empirical studies of effects of inspections and fines on pollution levels and the determinants of the monitoring and enforcement activities of regulators, respectively, for a less developed country (China).[1] There does not exist any example of this type of empirical work for Latin America.[2] This is a very important shortcoming because Latin America has a long tradition in water pollution control laws based on uniform emissions standards, but both public opinion and papers that have analyzed environmental policy in the region have regarded them as poorly enforced [see (33), (13), (28) and (35)]. At the same time, new regulations for other media (like air) and new incentive based instruments are being developed and implemented in some parts of the region, but no effort has been made to empirically test the capacity to enforce these new regulations.

In this respect, previous empirical analyses in the US, Canada and China are of little guidance for a Latin American country given the obvious differences in institutional capacities and even political systems. This paper aims to start filling this gap by, first, empirically examining the determinants of the allocation of inspections by the municipal and the national government among industrial plants in Montevideo, Uruguay, and then

[1] There are a few other examples of empirical analyses of informal and formal pollution regulation in LDCs (see (29), (30) and (17)). But these studies, among other, have significant differences in the quality of their data as compared to the above-mentioned papers.

[2] Existing works explore other issues (see (3)), or have data limitations that make them not comparable (see (9), (6), (7), (12) and (14)). First, some of them do not have information on emissions or formal regulatory measures or both. Second, they are all cross-section studies. See (5) for a detailed description of these works and their data limitations and differences.

by empirically testing the effect of monitoring and enforcement actions of both the municipal and state governments on industrial plants' emissions of BOD_5 in Montevideo, and their probabilities of being in violation.[3] Also, a unique feature of this research with respect to past empirical studies is the availability of four sources of information regarding levels of pollution. One is the level reported by industrial plants, another is the level sampled by the municipal government, a third is the level sampled by the national government and the fourth is the level sampled by a private consortium that worked for the municipal government. This unique feature allows me to perform difference of means tests as a simple way to explore the presence or absence of under-reporting.

2. INSTITUTIONAL FRAMEWORK AND WATER POLLUTION REGULATION

Both the municipal government of Montevideo (Intendencia Munucipal de Montevideo, IMM) and the national government Environment Office (Dirección Nacional de Medio Ambiente, DINAMA) have jurisdiction over industrial water pollution control in the city. The allocation of responsibilities between them can be summarized as follows. The IMM is responsible for monitoring industrial effluents and enforcing emissions standards and the correct operation of effluent treatment plants. It is also the regulatory institution to which the plants report. The task of the National Environment Office (DINAMA), through the Division of Environmental Control (DCA), is to issue 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 DCA is in charge of "initial compliance", while the IMM is in charge of "continuous compliance". This institutional organization is result of the historical evolution of water pollution legislation. It was at the municipal level that the first regulations concerning

[3] BOD_5 is among the most important pollutants and is one of the two pollutants targeted by the municipal government and the Inter American Development Bank. It is also a pollutant that all plants emit and have to report.

industrial water pollution appeared in the sixties, almost twenty-five years before the creation of the Ministry of the Environment.[4] But the institutional organization is also the result of an informal agreement between the DINAMA and the IMM that took place in 1995, which was aimed at saving scarce monitoring and enforcement resources. Though the division of responsibilities was clear in theory, coordination between the two offices remained poor in practice. For example, the DINAMA continued to monitor plants even when they were not investing in their treatment plants. Lastly, if we add that the Ministry of the Environment suffers important budget constraints that prevent the complete swapping of responsibilities, it is very easy to understand why the IMM continues to play a role as significant as the DINAMA with respect to industrial water pollution in the city of Montevideo. The DCA's staff is composed of only five persons, who are not only in charge of monitoring and enforcing water pollution legislation, but also the rest of environmental legislation. Staffing is a bit better at the Industrial Effluents Unit of the IMM, where seven persons work, but they are only in charge of industrial emissions in Montevideo.

The pollution control instruments used are uniform emission standards. These are defined in terms of concentrations of pollutants, not in terms of quantities discharged. No absolute legal limits are established on the quantity of pollutants to emit.[5] Nevertheless, rather than simply enforcing emission standards, water pollution control is centered on the existence and correct operation of a treatment technology. In fact, the legislation does not sanction violations to emissions standards, only misoperation of the treatment plant.[6] Fines are set as an increasing function of the number of violations in record. This system

[4] Ordenanza sobre la Disposición de Aguas Residuales de los Establecimientos Industriales del Departamento de Montevideo, Decreto N° 13.982 de la Junta Departamental de Montevideo, 1967, and Reglamentación de la Ordenanza sobre la Disposición de Aguas Residuales de los Establecimientos Industriales del Departamento de Montevideo, Resolución N° 16.277 del Intendente Municipal de Montevideo, 1968.

[5] The only related regulation states that the total volume of effluent discharged must not be greater than 2.5 times the average volume emitted during an activity period for plants emitting to the sewage system, and 1.5 times for plants emitting to watercourses. These measures would prevent temporary overloads that could produce permanent effects on watercourses. The Decree also established that discharge authorizations are conditioned on the capacity of the municipal sewer, and that the Ministry of the Environment can mandate firms to control effluent volumes.

[6] "Decreto 253/79, Normas para prevenir la contaminación ambiental mediante el control de contaminación de aguas, 1979."

requires the firms to supply a considerable amount of information to the DINAMA in the application process for a discharge permit (26). They provide information regarding the production process (including maximum daily and monthly production, average water consumption, daily quantities of inputs used), a description of the characteristics of effluents and solid wastes generated, information on conditions of receptor bodies at the point of discharge, time schedules for the construction of the treatment plant and a description of its operation and maintenance.

Recognizing very low compliance rates and the difficult economic situation of the industrial plants of the city as a possible explanation for them, the municipal government of Montevideo implemented the "Industrial Pollution Reduction Plan" that relaxed the emissions standards and established a time schedule by which they would converge again to the original levels.[7] The Plan was supposed to give the firms considerable time to implement changes in abatement technology. Starting on March 1st 1997, the industries had almost three years before the standards converged again to the original levels, in December 31st 1999. A second observation is that regulators recognized wool washing plants and tanneries as the industries facing the greatest difficulty in complying. These plants had laxer standards in each period, and even more surprisingly, the BOD_5 standards for these two types of plants emitting to municipal sewers converged to a value that is higher than the original one (3,000 mg/l and 1,000 mg/l for wool plants and tanneries, respectively, compared to 700 mg/l set by the National Decree 253/79). According to conversations with inspectors at the Department of Environmental Control of the DINAMA, these inconsistencies have generated problems in enforcement because firms argue that they are complying with municipal standards while the DINAMA requires adjustments to meet emission standards set by the National Decree.

[7] Resolución Municipal N° 761/96, Plan de Reducción de la Contaminación de Origen Industrial, February 26th, 1996.

3. ACTUAL POLICY

The strategic plan that guides the IMM control policy was outlined in the Urban Sanitation Director Plan (Plan Director de Saneamiento Urbano), in execution since 1992 with funds from the Inter-American Development Bank. In general terms, this is a plan for the extension of the municipal sewage system to several parts of the city. Concerning the water pollution policy, these works would reduce effluents discharged to city streams by redirecting them into the sea through two discharge pipes. Towards this objective the IMM undertook the third stage of the Urban Sanitation Plan for the city of Montevideo (PSUIII).[8] This plan is key to understanding the pollution control policy of the IMM and it needs to be taken into account when interpreting the empirical results in Section 7 regarding the effectiveness of the emissions standards enforcement policy. The objectives of the PSUIII included the development of a Monitoring Program for controlling industrial pollution and the quality of the city's water bodies (see (25)). The Monitoring Program was executed between 1999 and 2001 by the private consortium Multiservice-Seinco-Tahal (SEINCO). The major activities of the Monitoring Program included inspection, supervision and sampling of industries to determine level of compliance with emissions standards and establishment of the monitoring frequency, duration and procedure of emissions by industry class

Industrial water pollution in Uruguay is based on a system of self-reporting. Self-reports are sent to the Industrial Effluents Unit of the IMM, although some plants send them also to the Department of Environmental Control of the DINAMA voluntarily.

Reports include monthly levels of (1) production, (2) tap and underground water consumed, (3) energy consumed (electricity, wood, fuels), (4) number of employees and days worked, and (5) volumes of emissions and their concentrations of pollutants. Reporting periods are November – February, March – June and July – October. Inactivity periods should also be reported. Failing to send a report on time and in the correct form could lead to fines to the industry and an observation to the professional in charge. In

[8] Contract signed in November 1996, Loan 948/OC-UR

theory, the plants have to send the reports within the two weeks that follow each reporting period. But actually this requirement is not enforced.

Two types of regular inspections exist, with and without effluent sampling. Sampling inspections are those in which the inspectors take samples from the plant's effluents for latter analysis. These inspections always include an evaluation of the treatment plant performance as well as general questions regarding the economic situation of the firm, including changes in levels of production, or special events that could affect the effectiveness of the effluents treatment process. Non-sampling inspections include the latter evaluation and general questions but they do not include a sample of the plant's effluents. Possible reasons for not sampling may be that the plant is not working at the time of the inspection, or that the plant is not discharging at the time of the inspection.[9]

4. DATASET

I use three sources of information to construct my dataset. The core information comes from the Municipal Government of Montevideo. This is comprised of information regarding production and pollution of industrial plants, plus information regarding monitoring and enforcement activity of the IMM on these plants. The information on production and pollution is obtained from the four-month reports of the plants, described in Section 3. The information on inspections is comprised of the number of sampling and non-sampling inspections done per month per plant, and the result of the sample in terms of mg/l of BOD_5. The information on fines levied by the IMM is comprised of the number of fines levied on each industrial plant per month and their amounts. The sample period for all these variables is July 1996 – October 2001, except for fines, which is May 1997 – October 2001.

My second source of information is the Environmental Control Division (DCA) of the Ministry of the Environment. This information includes number and results (in terms of

[9] This discontinuity of discharges presents a problem for the DCA inspectors, who have very rigid time schedules for inspections in Montevideo because they also have to inspect firms in the rest of the country.

BOD_5 mg/l) of sampling inspections, and number of non-sampling inspections. It also includes the total number of compliance orders issued by the DCA. Past the due date, the DCA issues a note communicating to the firm that it is potentially subject to a fine due to non-compliance with the previous order. I called this type of action "fine threats". Finally, in the case of fines, I have both the number of fines per month per plant and the amount. The sample period for all the DCA variables is June 1996 – October 2001.

Finally, my third source of information is the private partnership MULTISERVICE-SEINCO-TAHAL (SEINCO) that was in charge of the Monitoring Program that the IMM implemented in 1999, financed by the IADB, mentioned in Section 3. This information is comprised of the number and result of the sampling inspections conducted by SEINCO. The period during which SEINCO inspected plants was April 1999 – September 2001.

Table 1 gives a summary of all the information just described.

Table 1: Data set description

	IMM	DCA	SEINCO
Monitoring And Enforcement Variables	# of sample inspections # of non-sample inspections Result of BOD_5 sampled # of Fines Amount of the fines	# of sample inspections # of non-sample inspections Result of BOD_5 sampled # of compliance orders # of fine threats # of Fines Amount of the fines	# of sample inspections Result of BOD_5 sampled
Period	July 1996 – October 2001 except Fines (from May 1997)	July 1996 – October 2001	April 1999 – September 2001

My database includes seventy-four (74) industrial plants located in Montevideo. The selection of these 74 plants is not random. First, they are all privately owned plants. Public industrial plants do not report emissions to the IMM. Second, they were selected from a list of industrial plants that were being sampled by SEINCO during the years 2000 and 2001. Most of these plants were also the ones that were regularly inspected by the IMM. From a maximum of eighty-seven plants, I excluded twelve (12) plants that reported less than six (6) times during the thirteen (13) reporting periods in my sample although they were active throughout the 13 periods. From the remaining 75 I had to exclude one more because it was not reporting BOD_5 emissions; it reported only metals emissions. Consequently, conclusions from my analysis must be interpreted according to this sample selection bias. It can be said though, that the plants in the sample are responsible for more than 90% of the total industrial organic pollution in the city.

I present the descriptive statistics for the input and pollution variables in Table 2 and the monitoring and enforcement variables in Table 3.[10]

Table 2: Descriptive Statistics for Input and Pollution Variables
(Sample July 1997 – October 2001)
Total Potential Observations: 3,848

Variable	Mean	Median	Std. Dev.	Missing Values
BOD_5 (mg/l)	1,031	370	2,334	952
Effluent flow (m3/day)	203	52	453	1,034
Tap water (m3/month)	3,848	784	8,271	638
Underground water(m3/month)	2,793	750	4,873	1,279
Electricity (Kwh/month)	179,409	68,000	278,828	449
Fuel (m3/month)	34	12	50	862
Days worked (per month)	22	23	4.6	594
Number of employees)	122	60	276	342

The DCA inspected a lot less than the IMM during the period July 1996 - October 2001. Out of a total of 760 inspections by the two regulatory offices on the seventy-four industrial plants in the sample, the IMM conducted a total of 549 inspections while the DCA only performed 211. Furthermore, 401 of the IMM inspections (73%) were sampling inspections; while for the DCA sampling inspections were 122 (58%).

[10] Descriptive statistics for the levels of production are not presented for space reasons. Also, gas and firewood consumption are not included in the table. The IMM did not ask firms to report gas consumption before 2001, and in 2001 only one plant reported gas consumption in two reporting periods. The problem with firewood is that not all of the industrial plants in the sample use firewood as an input and not all of those who did not use it reported zero consumption. Instead, a value was missing in the respective cell. Given these, I discarded these two variables from the analysis.

Table 3: Descriptive Statistics for Monitoring and Enforcement Variables

IMM and DCA

(Sample July 1996 – October 2001)

Total Observations: 4,736

	Units of Measure	Mean	Std. Dev.	Maximum	Sum	Number of Plants
			IMM			
Sample Inspections	#	0.085	0.286	3	401	74
Result (BOD_5)	(mg/l)	1,582	3,894	49,925		74
Non-sample Inspections	#	0.031	0.212	6	148	74
Total Inspections	#	0.116	0.378	9	549	74
Inspections	Dummy	0.106	0.308	1	502	74
Fines	#	0.003	0.052	1	11	74
Fine ($)	$	1,404	1,050	3,000	15,450	74
			DCA			
Sample Inspections	#	0.026	0.158	1	122	74
Result (BOD5)	(mg/l)	1,102	1,720	10,400		74
Non-sample Inspections	#	0.019	0.137	2	89	74
Total Inspections	#	0.045	0.210	2	211	74
Inspections	Dummy	0.044	0.204	1	207	74
Compliance Orders	#	0.024	0.155	2	112	74
Postponements	#	0.013	0.123	2	60	74
Fine threats	#	0.015	0.126	2	72	74
Fines	#	0.001	0.029	1	4	74
Fine ($)	$	3,375	750	4,500	13,500	74
			SEINCO			
Simple Inspections	Dummy	0.180	0.384	1	663	71
Results (BOD_5)	(mg/l)	1,184	2,545	38,000		71

Notes:

(1) Observations for fines levied by the IMM were available from May 1997 (3,996 observations).

(2) Statistics for amount of fines are over the non-zero observations

(3) Dollars of October 2001.

Finally, it is interesting to note that that fines were very rarely levied in spite of extremely frequent reported and discovered violations. I present the descriptive statistics of the variable "extent of the violation" in Table 4. This variable is equal to emissions of BOD_5 (mg/l) minus the concentration standards set in the legislation, censored at zero. I also present the descriptive statistics of a compliance status 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 4: Descriptive statistics for violations

	Extent of the Violation (Censored at zero)		Compliance Status (Violation = 1, Compliance = 0)	
	Original Standards	Plan's Standards	Original Standards	Plan's Standards
Mean	641.5	338.8	0.5421	0.4069
Median	20.0	0.0	1.0	0.0
Maximum	38143	17125	1.0	1.0
Std. Dev.	1906.7	1124.1	0.4983	0.4914
Observations	2699	2192	2699	2192

Violations were frequent, even when measured as emissions in excess of the laxer standards. Forty one percent (41%) of the reported BOD_5 levels were out of compliance with the emission standards, and only twenty six (26) plants of the total sixty-nine (69) reported to be in violation less than twenty percent (20%) of the time. The number of violations as a percentage of the number reports never decreased below 25%, or 41% if we consider the original standards. In spite of this, the IMM levied only 11 fines and the DCA only four fines during the same period.

5. MISSING VALUES

As evidenced by Table 2, I have missing values (MV) in my panel. Observations are missing either because a plant did not report in a given period, in which case I have a missing value for the entire set of variables for that period, or because the report had missing values for one or a subset of variables. I call the first case "unit non-report" and the second case "item non-report".

There were a total of sixty-two (62) non-reports over a potential 962 observations (74 plants times 13 reporting periods). Six of these correspond to four plants that ceased production (for different reasons). Twelve correspond to reported "no-activity" periods of three different plants.[11] Sixteen correspond to three plants that started business in periods

[11] I treated these as missing values because in some cases the firms indicated (usually in a letter to the Director of the Industrial Effluents Unit of the IMM) that they were producing "very low" quantities and therefore it was not worth reporting emissions. Even more, in one case the letter was followed by three non-reports in the following periods without any clear information regarding the exact point in time in which production re-started.

four, five and nine, respectively. The remaining twenty-eight correspond to “random” non-reports.

There are several reasons for item non-reports. One is that some firms never report a specific variable. Others report a specific variable unsystematically. For example, in the case of underground water consumption some firms report zero consumption in some periods and do not report in others.[12] Finally, other values appear to be randomly missing.

Taking into consideration item and unit non-reports there were a total of 5,557 observations missing for the inputs and pollution variables described in Table 2 plus the levels of production reported by the industrial plants, out of a total of 40,924 possible observations. In other words, 13.6% of the data set was missing.

The problem with MV is that estimation based only on the complete observations (those having no missing values) may bias parameter estimates if the data is not missing at random or the selection rule is “ignorable” (see (23)).

Verbeek and Nijman (1992a) proposed a formal test for “ignorability” in linear regression models of panel data. The test is worth performing because of the complexities involved in estimating a panel incorporating the selection rule. Nevertheless, I cannot perform the test because I have zero observations for my balanced sub-panel. (I have no month in which all the 74 plants reported). Consequently, I proceed with my unbalanced panel. This option is justified by three reasons. First, and most obvious, I have no choice, other than to perform no estimation at all. Second, that it is fairly simple to conclude that there exists selection bias in my data set due to non-reporting. I have twelve (12) observations missing as a consequence that the plants informed “no activity” or “very low” activity. Missing-ness is then clearly related to the level of production. The selection rule is not independent, among other possible things, of the overall economic situation of firms or seasonality. These twelve cases make my selection rule not ignorable. Third, I do not think this source of non-ignorability of the selection rule is important in terms of bias because in most cases plants were actually not working and not emitting, as proved by inspections performed in those cases. If this is true, and if I

[12] Given the importance of underground water consumption in the analysis I opted to fill-in these missing values instead of discarding it as I did with firewood.

assume that item non-responses are missing at completely at random, which I do, then the missing observations do not hide any unknown information.

In spite of the fact that I proceed with an unbalanced panel, I impute for the item non-responses before estimating my parameters of interest. The reason is that item non-responses account for 55.4% of the total 5,009 observations missing for the input and pollution variables.

Several methods are used in the applied literature and others are proposed in a more recent theoretical literature to deal with missing values. The issue when selecting a method to deal with missing values is that some of them (for example, imputing means) may reduce the efficiency of the final estimators. A review of these methods, along with a discussion of their properties, can be found in (23) and (22). For the case of panel data, a review of the literature of incomplete panels and selection bias can be found in (36).

There are basically two criteria to follow when imputing values for item non-reports: conditional mean imputation and multiple imputation (see (22)). Conditional mean imputation methods are based on (4), and (2). The basic idea is to use the information on the observed Xs or on the observed Xs and Ys to fill in missing values, correcting for the variances and covariances. Least squares on the filled-in data produce consistent estimates assuming that the item non-responses are missing "completely at random" (see (23)).

Multiple imputation is proposed as a way to handle the problem that whatever the conditional mean imputation procedure, "estimated standard errors of the regression coefficients from ordinary least squares or weighted least squares in the filled-in data would tend to be too small, because imputation error is not taken into account." (see (22), p. 1232). By multiple imputation, basically, one imputes $m \geq 2$ values for each missing observation to obtain m different data sets. With each data set one obtains the desired estimates and "averages" them to obtain a final parameter estimate and variance estimate that "correct" for the underestimation of variances produced by filling in missing observations. (see (31)).

Both conditional mean and multiple imputation methods were developed and applied for cases of cross-section data and therefore share a problem when applied to panel data: it makes little sense to fill in item non-responses of one plant conditioning on information observed for the rest of the plants, with different technologies, management and output.

I solved this problem by performing the imputations within plants. This way I not only preserve between-plant variability, minimizing bias and variance problems for the final estimates, but I also use plant-specific information about the missing values.[13] Within-plant imputation leaves aside multiple imputation because this would produce *m* data sets for each different plant, and there is no clear way to handle all this information to obtain the final panel estimates. Consequently, I use an iterated Buck procedure within plant to impute for item non-reports, in the spirit of the suggestion made by Beale and Little. To perform this procedure I construct the following variables for each plant: (1) *WATER:* Total water consumption (in m^3/month) equals the sum of tap water and underground water consumed; (2) *ENERGY = EL*3.6 + FUEL*43,752.06*: Total energy consumption in mega joules (MJ), where *EL* is the electric energy consumed in Kwh/month and *FUEL* is the quantity of fuels consumed per month in m^3; (3) *LABOR* = equal to the total number of days worked in the month times the total number of employees in that month; (4) $POLLUTION = FLOW*BOD_5*1000$: Total organic pollution discharged in (mg/day), where BOD_5 was already defined and *FLOW* is the average flow level of discharges, in m^3/day; (5) *PRODUCTION* = Quantity produced by month.[14] The original variables were fitted using these constructed variables. I estimated the auxiliary linear regressions with the variables in natural logarithm forms. These did not necessarily provide better fits than auxiliary regressions with variables in their original form, but they are closer to "the spirit" of a Cobb-Douglas type of production function used ahead.[15]

Finally, I do not use the monitoring and enforcement variables in this imputation for two reasons: first, I conserve degrees of freedom in the auxiliary regressions within

[13] An example of the latter is to use monthly volumes of effluents discharged divided by days worked in the month to impute the monthly average effluent flow.

[14] In twenty-five cases this variable involved standardizing units of measure to be able to add different products.

[15] 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.

firms, and second, because it would be like cheating to use these variables to impute for the MV and then use the resulting data to test for their effect on pollution.

6. SPECIFICATION AND ESTIMATION ISSUES

6.1 THE INSPECTION EQUATIONS

During the period under study both the municipal (IMM) and national government (DCA) office monitored industrial plants in Montevideo. In fact, all seventy-four industrial plants were inspected at least two times by the IMM. The DCA inspected fifty-eight of these same plants at least once. The remaining sixteen plants were never inspected by the DCA. Parallel monitoring efforts of regulators were not coordinated. The two offices did not share information on monitoring and enforcement activities on a regular basis. Quite the contrary, information sharing was limited to specific and complicated cases. In fact, the correlation coefficient between the number of inspections of the two offices across time and plants is 0.16. These arguments validate the chosen course of action of estimating separate inspections equations for the IMM, DCA and SEINCO.

Apart from explaining the inspection strategies itself, the idea behind the estimation of these inspection equations is also to fit them to obtain probabilities of being inspected by each of these institutions that can be used as instruments for actual inspections in the BOD_5, load and violation equations.

6.1.1 The IMM Inspection Equation

Equation 1 was estimated for the IMM:[16]

[16] Table A.1 in the Appendix provides a list of all the variables used in this chapter and their definitions.

$$
\begin{aligned}
INSPIMM_{i,t} = {} & \gamma_i + \gamma_1 INSPIMMCUM_{i,t-1} + \gamma_2 INSPIMMOTHERCUM_{i,t-1} \\
& + \gamma_3 INSPSEINCOCUM_{i,t-1} + \gamma_4 FINEDIMMCUM_{i,t-1} + \gamma_5 VOL_t \\
& + \gamma_6 RF_{i,t} + \gamma_7 1997-1998_t \\
& + \gamma_8 DURINGPLAN_t + \gamma_9 STREAM_{i,t} + \eta_{i,t} \\
& i = 1,...,74; t = July1997,...October2001
\end{aligned}
\tag{1}
$$

where $INSPIMM_{i,t}$ is a dummy equal to one if plant i was inspected by the IMM in month t.

First of all γ_i represent the plant-specific fixed effect. Its inclusion is the result of a Hausman test that compares the conditional (fixed-effects) and the unconditional logit estimates. The Hausman chi-squared statistic was 98.7 clearly suggesting to reject the null of common intercept in the favor of the alternative of plant-specific fixed-effects.

Because fixed effects are never actually estimated in the conditional logit, the results of these tests suggest the following trade-off. On the one hand, without estimates for the fixed effects I cannot obtain predictions for the probabilities of inspections. On the other hand, if I specify an unconditional logit to be able to predict probabilities I do not recognize plant specific effects and I obtain inconsistent estimates of my parameters. The chosen solution was to estimate an unconditional logit to predict the probabilities and a conditional logit to interpret the estimated coefficients. The two models cannot be specified identically because the conditional (fixed-effect) logistic regression eliminates any variable without within-plant variability. What I present here and in the following sections are the conditional logit models. I do not present the results of the unconditional models.

In order to specify this inspection equation, first I considered that the strategy of the IMM inspectors obeyed five rules, according to what they declared in interviews. The first one was a "sample without replacement" rule. The IMM classified plants in "Priority 1" and "Priority 2" plants. Priority 1 plants (25 of the 74 plants in my sample) are the heaviest polluters in terms of organic pollution and metals. They account for 80% of this pollution. Interviewed inspectors declared that they try to visit "Priority 1" plants twice and "Priority 2" plants once every six months. But the data do not support this statement. Therefore, in order to capture the sample-without-replacement inspection strategy I included the number of inspections performed in the plant during the last twelve months (*INSPIMMCUM*$_{i,t-1}$) as explanatory variable.[17]

The second rule mentioned by IMM inspectors was that plants with worse compliance histories and those showing less cooperation with regulators were inspected more often. These plants were those that did not take the promised measures to abate emissions or delayed them. I included *FINEDIMMCUM*$_{i,t-1}$ to capture the level of cooperation.[18] This variable measures the number of fines imposed by the IMM against this plant in the last twelve months; the more the cumulative number of fines the less the cooperation of the plant in the recent past.[19] This level of cooperation perceived by regulators is not only a function of the recent formal history of the plant. It also depends on non-quantifiable facts on which inspectors based their decisions.[20]

Third, citizens' complaints also triggered inspections but were not included as an explanatory variable because of the unavailability of information about them. Nevertheless, interviewed inspectors declared that most of these complaints were not originated by "unusual" levels of discharges, but from smells or illegal points of discharge (e.g., streets, brooks) or when the public sanitary system below the streets collapsed.

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[17] I tried the cumulative number of inspections performed in the last six months instead of twelve months, but the model performed better with twelve months in terms of goodness of fit and both the Akaike and Schwarz information criteria.

[18] The inclusion of the number of detected violations in the last twelve months did not improve the fit of the model. This result is consistent with the policy approach of the period. Effectively, during this period the enforcement efforts were not so much directed at enforcing standards but at decreasing emissions. Towards this end was that the IMM implemented the Industrial Pollution Reduction Plan relaxing emissions standards.
Also, the cumulative amount of fines was included instead of the cumulative number. This did not change the results either.

[19] I do not have information on intermediate enforcement actions (e.g., compliance orders) issued by the municipal government of Montevideo, just those issued by the national government office, DINAMA.

[20] An example is the following: sometimes inspectors are kept waiting at the plant entrance for the length of time needed to make some quick cleanings and other measures (like diluting) to comply with the emissions standards. This is more typical in small plants, with lesser time of effluents retention. Another example is the quickness of response to suggested changes. It is worth noting that this makes the effectiveness of water pollution control very dependent on those specific inspectors with long experience in the job. In other words, a good deal of the compliance history of plants is lost when an inspector retires or is appointed to another office.

Fourth, the failure to report in subsequent periods also triggered inspections according to the IMM inspectors. As a result, the number of reporting failures in the previous two reporting periods ($RF_{i,t}$) was also included as an explanatory variable.[21]

1997-1998 is another dummy variable equal to one in the months of these two years during which the IMM inspectors conducted special monitoring campaigns due to the delay in the implementation of the Monitoring Program by SEINCO. It is interesting to note that IMM inspectors received extra IADB-financed payments for these campaigns.

DURINGPLAN refers to the Industrial Pollution Reduction Plan implemented from March 1997 to December 1999. This variable, a dummy equal to one during these months, was included because the IMM could have changed its monitoring strategy given that its objective during these months was to give more time to plants to incorporate abatement technology.

BOD_5 emissions standard for plants emitting directly into waterways is 60 milligrams per liter (mg/l), while it is 700 mg/l for those emitting into the sewage system. A dummy variable indicating whether the plant was emitting directly into a water body was also included to capture any possible effect of this on the probability of being inspected. This variable is *STREAM*, equal to one if the plant emits directly into a water body.

In addition to the variables included to capture these rules, other variables were included to capture other determinants of IMM inspections, for example, $INSPIMMOTHERCUM_{i,\,t-1}$. This variable measures the cumulative number of inspections performed by the IMM in the rest of the plants. Inspectors knew that the rest of the plants were aware of inspections performed at a specific plant, particularly those in the neighborhood, and that this could have molded their expectations regarding a possible inspection. On the other hand, if the IMM monitoring activities were affected by important budget constraints, as they actually were, the sign of this variable's coefficient

21 In the first six months of 1997 the IMM implemented a new enforcement strategy. It issued a fax to every plant in its database explaining the new four-month Reporting Form format and communicated to the plants that the municipal government was undertaking a new plan for pollution control. For that reason, in the first reporting period I set the reporting failure history of every plant equal to zero as an indicator that a new enforcement period had begun.

would be negative, indicating that the higher the number of inspections performed on other plants in the recent past the smaller was the probability of this plant being inspected given the cost of monitoring campaigns. Therefore, the sign of this variable's coefficient remains an empirical matter.

Another important determinant of IMM inspections during part of the analyzed period was the implementation of the "Monitoring Program", financed by the Inter American Development Bank and in charge of the private consortium SEINCO. This consortium conducted regular inspections on industrial plants during 1999-2001. The IMM took advantage of this situation, saving on monitoring resources. $INSPSEINCOCUM_{i,t-1}$, the cumulative number of inspections performed by SEINCO on a plant in the last twelve months, measures this effect.

Also, the Uruguayan industrial sector went through an important contraction during part of the analyzed period. In particular, the industry production volume index dropped 8.6% on average in 1999 and 7.2% in 2001. (During 2000 it increased 2%). The contraction was larger as measured by the industry real GDP: 23% between 1996 and 2001, with an average drop of 4% during the period 1997 – 2001 and 8% during the period 1999 – 2001.[22] Although not recognized by authorities, as a consequence of this contraction, inspectors may have eased or loosened their enforcement pressure on plants, since it was precisely the "difficult economic times" that inspired the Industrial Pollution Reduction Plan. I included the monthly level of the industry production volume index (*VOL*) to capture this possible effect.

Finally, unusually high levels of reported pollution sometimes triggered an inspection, although very rarely according to UEI inspectors. One reason is that obviously it cannot be optimal for plants to report "peaks" of their emissions. But it is not easy to construct a variable capturing the effect of unusual levels of reported emissions either. Many plants during the analyzed period sent their reports in the final month of the following reporting period. In other words, regulators were looking at a picture of the plant that was at least four months old. Other plants reported immediately after the end of

[22] The differences in the variation of the volume index (constructed by the National Statistics Institute) and industrial GDP (constructed by the Central Bank) are due to differences in weight of the different sectors in the construction of both indexes. I chose the first one because of monthly availability.

the reporting period. In short, regulators did not receive the information on emissions at the exact point in time in every period. This complicated the possibility of constructing a variable indicating unusual level of emissions because it was impossible to know at what point in time the regulator was looking at the information so as to decide on an inspection. For this reason, I opted to include no lagged indicator of reported pollution.[23]

The following variables had to be discarded in the conditional logit model, but were included in the unconditional specification used to fit the probabilities of being inspected. First, the priority group to which the plant belongs (PTY_i , equal to 1 if the plant is a Priority 1 plant). Second, two dummy variables: *TANNERY* for tanneries and *WOOL* for wool washers.[24] Apart from classifying industrial plants according to their priority, the IMM also targeted tanneries and wool washers. The reason for this is that the IMM, in accordance with the IADB, targeted its control efforts at two pollutants, Chromium and BOD_5. These two industries were the most important sources of these pollutants, respectively.

Finally, $\eta_{i,t}$ is the error term, assumed to be identically and independently distributed with zero mean and to have a logistic distribution.

6.1.2 The DCA Inspection Equation

The inspection equation proposed for the DCA was:

$$\begin{gathered} INSPDCA_{i,t} = \alpha_i + \alpha_1 INSPDCACUM_{i,t-1} + \alpha_2 INSPDCAOTHERCUM_{i,t-1} \\ + \alpha_3 EADCACUM_{i,t-1} + \alpha_4 VOL_t + \alpha_5 CARRASCO1999_t \\ + \alpha_6 STREAM_{i,t} + \upsilon_{i,t} \\ i = 1,...,74; t = July1997,...October2001 \end{gathered} \tag{2}$$

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[23] In spite of this I ran a model with the average BOD5 level of the plant in the last six months as an explanatory variable. The resulting coefficient was extremely low (0.00008) and insignificant. The overall fit of the model increased merely 0.000276 as measured by the McFadden R square.

[24] I included sector dummies in place of these two dummies to explore the results. The sector dummies were neither significant nor did they improve the fit of the model in the unconditional regression.

where *INSPDCA* is a dummy equal to one if plant i was inspected in month t.

α_i represents the plant-specific fixed effect. Its inclusion is also the result of a Hausman test. The value of the chi-squared in this case was 91.48.

The first two variables (*INSPDCACUM* and *INSPDCAOTHERCUM*) are defined exactly as *INSPIMMCUM* and *INSPIMMOTHERCUM*, and are included for the same reasons. $EADCACUM_{i,t-1}$ is the cumulative number of compliance orders, fine threats and fines issued by the DCA to the plant up to t-1.[25] *VOL* and *STREAM* are the same variables included in the IMM inspection equation. Also, during 1999 the National Environment Office (Direccion Nacional de Medio Ambiente, DINAMA) performed a special monitoring campaign on those plants in the basin of the Carrasco Stream. This campaign was the result of an agreement between the DINAMA and a non-governmental organization dedicated to fighting pollution of this stream. I included the dummy *CARRASCO1999* for this reason. Finally, I assume a logistic distribution for the errors in this equation for the same reason given for the IMM equation.

The DCA also targeted tanneries and wool washers, but, again, the corresponding dummies (*TANNERY* and *WOOL*) were dropped from the conditional logit due to perfect collinearity. Notwithstanding, they were included in the unconditional model used to fit the probabilities.

6.1.3 The SEINCO Inspection Equation

The specification of the SEINCO inspection equation is:

$$\begin{aligned} INSPSEINCO_{i,t} &= \beta_i + \beta_1 INSPSEINCOCUM_{i,t-1} + \beta_2 INSPIMMCUM_{i,t-1} \\ &+ \beta_3 INSPDCACUM_{i,t-1} + \beta_4 STREAM_{i,t} + \delta_{i,t} \qquad (3) \\ & i = 1,\ldots,74; t = \text{July 1997},\ldots\text{October 2001} \end{aligned}$$

[25] Separating EADCACUM into the cumulative number of enforcement orders, the cumulative number of fine threats and the cumulative number of fines did not improve the results.

β_i represents the plant-specific fixed effect and was included after running the corresponding Hausman test and obtaining a value of 238 for the chi-squared statistic. *INSPSEINCOCUM* is the cumulative number of SEINCO inspections. *INSPIMMCUM* and *INSPDCACUM* were included to test how SEINCO used the information pertaining to the monitoring activity of the two agencies to develop its own. Finally, according to interviews, SEINCO also inspected "Priority 1" plants more frequently and targeted tanneries and wool washers because of their importance in terms of organic and metal pollution. Again, these variables are not included in the specification above because this one corresponds to the conditional logit model, but they were included in the unconditional model used to fit the probabilities of being inspected.

6.2 THE POLLUTION EQUATIONS

6.2.1The BOD_5 Equation

Equation (4) is a linear pollution equation in the spirit of Magat and Viscusi (1990), Laplante and Rilstone (1996) and Dasgupta, et al. (2001). It assumes a Cobb-Douglas technology.

$$\begin{aligned} \ln(BOD5_{i,t}) &= \lambda_1 \ln(P_{q,t}) + \lambda_2 \ln(Labor_{i,t}) + \lambda_3 \ln(Water_{i,t}) \\ &+ \lambda_4 \ln(Energy_{i,t}) + \lambda_5 \ln(Flow_{i,t}) + \lambda_6 TECH_{i,t} \\ &+ \lambda_7 PINSPIMM_{i,t} + \lambda_8 PINSPDCA_{i,t} + \lambda_9 PINSPSEINCO_{i,t} \\ &+ \lambda_{10} INSPIMMCUM_{i,t-1} + \lambda_{11} INSPDCACUM_{i,t-1} + \lambda_{12} FINEDIMMCUM_{i,t-1} \\ &+ \lambda_{13} EADCACUM_{i,t-1} + \lambda_{14} DURINGPLAN_t + \mu_i + \nu_{i,t} \end{aligned} \tag{7.4}$$

i = 1, …, 74; t = July 1997, …, October 2001.

Equation (4) develops from the idea that the level of concentration of organic pollution in a given month, measured as Biological Oxygen Demand (BOD_5) in mg/l, is a function of two sets of variables, one reflecting the marginal benefits of pollution (i.e., the value of the marginal productivity of pollution) and another reflecting the marginal expected cost of pollution.

Marginal benefits of pollution are represented by the price of the final good (P_q) and the input variables *Labor*, *Water*, *Energy* and *Flow*. Marginal expected costs of pollution are represented by the monitoring and enforcement variables. These are comprised of the probabilities of being inspected by the municipal and national governments ($PINSPIMM_{i,t}$ and $PINSPDCA_{i,t}$) and by the probability of being inspected by SEINCO ($PINSPSEINCO_{i,t}$). These three variables are included to capture the effect of future possible enforcement actions due to today's pollution decisions. They were obtained by fitting the IMM, DCA and SEINCO inspections equations. Provided that there is no contemporaneous correlation between the error term in the pollution equation ($v_{i,t}$) and the error term in the inspection equations ($\eta_{i,t}, \nu_{i,t}, \delta_{i,t}$), these fitted values will be uncorrelated with $v_{i,t}$, and a least squares estimator will yield consistent estimates of the parameters of the pollution equation.[26]

But pollution today is also the result of past monitoring and enforcement actions. This is the reason for including the cumulative number of inspections performed during the last twelve months by the municipal government (*INSPIMMCUM*) and the national government (*INSPDCACUM*) and the cumulative number of fines levied by the municipal government (*FINEDIMMCUM*) and the cumulative number of intermediate enforcement actions and fines levied by the national government (*EADCACUM*).[27]

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[26] Since the reduced form for the inspection equation is identical to the (structural) inspection equation, my estimation procedure is the same as 2SLS but in a system that is not simultaneous.

[27] 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. Also, these types of measures were as uncommon as fines during the period. Another form of penalty implemented was to make professionals in charge of treatment plants legally responsible for sending false reports. According to the IMM's Industrial Effluents Unit Director, this was done as an explicit enforcement mechanism. The objective was to persuade professionals about the dangers of falsifying information and to act on reluctant plants through them. According to this Director, this type of expected penalty may have had an important impact on emissions levels because plants reluctant to decrease emissions may have encountered increasing difficulties in finding professionals in the market who were willing to cheat at their own personal cost. Apart from its apparent effectiveness, this strategy, which in a sense could be seen as a deviation from the classical theoretical model of enforcement, seems also optimal in terms of institutional compatibility. High fines are rarely feasible to apply in less-developed countries where firms suffer from important cash flow constraints. These alternative penalties are easier to apply because they do not imply a cash payment. At the same time, they do imply significant costs to the firm,

Some cases in the previously cited literature include the contemporaneous number of inspections or a dummy as an explanatory variable to indicate whether the plant was inspected in that month. Those who did not consider under-reporting to be an issue included it as another determinant of pollution. These cases estimated pollution and inspections as jointly determined in a system of two equations. Those who did consider the problem of under-reporting, like Shimshack and Ward (2002), did this as an "imperfect" and "weak" test for self-reporting accuracy. My approach was to use fitted values obtained from the inspection equations which would serve at the same time as an econometric instrument for actual inspections and as a proxy for probabilities of being inspected. To test for the presence of under-reporting I used the information on BOD_5 samples by the IMM, DCA and SEINCO and conduct difference-of-means tests between these and the BOD_5 reported levels.

The reason for including intermediate enforcement actions apart from fines is that with only 15 fines in the whole period (despite frequent violations) it is reasonable to conclude that regulators intended to reduce emissions via these intermediate actions. These may have had their own deterrent effects. This deterrent effect could be explained because fines are not instantaneously applied after a violation is reported or discovered by an inspection. Instead, firms face an increasing probability of being fined. Of course this probability and the amount of the fine is uncertain for the firms. However, firms learn by observing past responses of regulators to violations.[28]

Eight firms modified their treatment technology during the period, either by constructing nonexistent treatment plants or by significantly modifying existing plants.[29] I included the variable *TECH*, a dummy equal to one in the month that the plant incorporated abatement technology and thereafter, to control the effect of changes in treatment technology on BOD_5 levels.

either directly (through closing) or indirectly (through the professionals' incentives). Unfortunately, it was impossible to measure their effects.
Finally, INSPSEINCOCUM (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.

[28] I ran a version of this equation separating the cumulative number of compliance orders, the cumulative number of fine threats and the cumulative number of fines issued by the DCA. Results did not change.

[29] One more plant incorporated technology the month before the beginning of my study period and two more during 1996.

The last explanatory variable is DURINGPLAN. This variable is the same dummy that was included in the IMM inspection equation. Its value is one during the months of the Industrial Pollution Reduction Plan and zero afterwards. The idea of including this variable in the pollution equation is to test for the presence of different reporting and emitting behavior of plants during the plan. This is possible because during these months emission standards were laxer. With it the IMM intended to give plants time to adopt abatement measures while at the same time complying with pollution regulations. The inclusion of this variable measures the success of the plan.[30]

The parameter μ_i is a plant-specific effect. I chose a fixed-effects model, as opposed to a random-effects model, because I am basing my inference on these 74 specific plants, which were not randomly selected from a large population and are responsible for around 90% of the industrial emissions in the city. I did not perform formal tests for the unit effects. To perform these tests under the assumption of non-spherical errors I would have to invert the variance–covariance matrix of the errors and this is not possible when number of cross-sections (N=74) that is larger than the number of time periods (T = 52). In spite of this, I performed a Chow test assuming that the errors were spherical. The test strongly suggested rejecting the null hypothesis of common constant terms.[31]

Finally, $v_{i,t}$ is the stochastic disturbance. Following Park, the panel structure of the errors can be: (1) Panel Heteroskedastic, (2) Contemporaneously Correlated; and (3) Common Serially Correlated or (4) Plant-specific serially correlated.

I have two plants that do not have contemporaneous (common) observations and therefore I cannot test the validity of the assumption of no contemporaneous correlation of the errors that underlies the application of Arellano's robust standard errors. Nevertheless, this assumption is justified by the fact that the unbalanced nature of the panel greatly diminishes the number of observations to calculate the covariances $\hat{\sigma}_{ij}$.

[30] One caveat to this conclusion is stressed in the next chapter. The after-plan period coincided with one of the most important recessions of the Uruguayan economy in its entire history. As a result, an interpretation of the success of the plan according to a positive sign of the DURINGPLAN dummy could be misleading.

[31] The unrestricted model in this case is the FE model and the pooled model is the common-constant OLS model. The value of this statistic for this test was 71.69 > F(73,2705].

Given that I have no observations that are common to all of the cross-sections, the estimated residual covariance matrix would be formed by temporally mismatched sources. While this procedure is consistent (as the number of observations within cross-sections approaches infinity), it is not likely to be a good estimator in this setting.

The Durbin-Watson statistic of the original regression was 1.2812. This value suggested rejecting the null hypothesis of non-autocorrelation of the errors in favor of the alternative of first-order autocorrelation. A classical Chow test extended for the case of N linear regressions, one for each plant, with the restricted model being the pooled model $v_{it} = \rho v_{i,t-1} + \varepsilon_{it}$ and the unrestricted model being: $v_{it} = \rho_i v_{i,t-1} + \varepsilon_{it}$ was used to tests for plant-speficic versus common autocorrelation of the errors. The value of F obtained was 1.4509. The critical value for tends to one, therefore, the test suggests that the null hypothesis of common autocorrelation be rejected in favor of the alternative hypothesis of plant-specific autocorrelation.

Finally, I test for the presence of panel heteroskedasticity with three different tests: Bartlett, Levene and Brown-Forsythe. The results of these tests are presented in Table 6. All the tests in this table suggest rejecting the null hypothesis of panel homoskedasticity in favor of the alternative that not all of the plant-specific errors' variances are the same.

Table 6: Test for the Equality of Variances Between Residuals

Sample: 1997:07 2001:10
Included observations: 52

Method	Df	Value
Bartlett	73	1194.6
Levene	(73, 2812)	8.3630
Brown-Forsythe	(73, 2812)	6.9412

The natural estimation approach would have been to use feasible generalized least squares (FGLS), but I cannot estimate my model using FGLS because the error covariance matrix is not invertible.

The method chosen to avoid the singularity of $\hat{\boldsymbol{\Sigma}}$ and at the same time to use the information of the 22 (74 – 52) plants that I have "in excess" of T was to obtain consistent point estimates of my parameters and then calculate robust standard errors for these estimates.[32] This method not only circumvents the impossibility of applying FGLS to produce consistent estimates of the parameters but it also allows me to draw correct inferences about the coefficient estimates.[33]

Therefore, I first ran a least squares dummy variables (LSDV) model to obtain residuals to transform the data as in Cochrane-Orcutt. With the transformed data I run a second LSDV to estimate the parameters of the BOD_5 equation and the LOAD equation. Because my T is "large" (i.e., 52) this allows me to get consistent estimates of the "fixed effects". With the residuals of the second LSDV, I calculate Arellano's (1987) robust standard errors. These assume no contemporaneous correlation and are robust to panel heteroskedasticity and serial correlation. The reason for not calculating Arellano's robust standard errors with the original data and instead transforming the model to eliminate autocorrelation of the errors first is that this technique assumes that N is large and T is small and the asymptotic results are derived as $N \to \infty$. In my panel, although it is true that N>T, it is also true that T=52 cannot be considered small. Therefore, by transforming the data to eliminate the serial correlation of the errors first I am taking into consideration's Arellano's (2003) cautionary note that when T is not small the robustness of this technique to serial correlation may decrease.[34]

[32] I am grateful to Manuel Arellano for suggesting this to me via e-mail communication.

[33] A considered but discarded course of action was Panel Corrected Standard Errors (Beck and Katz, 1995 and Beck et al., 1993). I did not use Panel Corrected Standard Errors mainly for two reasons. First, the motivation of Beck and Katz (1995) for suggesting them was the overconfidence produced by Park's (FGLS) standard errors, a point already made by Freedman and Peters (1984). My motivation here is somewhat different since I cannot use FGLS in the first place due to the fact that N>T. Panel Corrected Standard Errors were developed for panels with T>N. The second reason is an empirical one. I have two plants (#52 and #72) that did not have contemporaneous (common) observations. Furthermore, the unbalanced nature of the panel greatly diminishes the number of observations to calculate the covariances $\hat{\sigma}_{ij}$. In other words, I cannot calculate all $\hat{\sigma}_{ij}$ to form $\hat{\Omega}$.

[34] I thank Gabriela Sanromán for pointing this out to me.

6.2.2 The Load Equation

The reason for estimating a BOD_5 pollution equation is that emission standards are defined in terms of concentration of organic matter (as measured by BOD_5). But, in addition, it is interesting to test whether the monitoring and enforcement strategy of regulators during the period had an effect on the total organic load discharged by plants and to compare it with the results obtained with the BOD_5 equation. An interesting issue that may arise with this comparison is whether regulators' effectiveness is masqueraded by the dilution of effluents in clean water, for example. The estimated load equation is specified exactly as the BOD_5 equation except for the obvious fact that it cannot include *FLOW* as an explanatory variable because *LOAD* is defined as BOD_5 times *FLOW*. *LOAD* is then measured in kg/day. The estimation of the load equation is performed exactly as the estimation of the BOD_5 equation.

6.2.3 The Violation Equation

In order to test the effectiveness of regulators regarding the compliance status of plants I estimate a conditional fixed-effects logistic model with a dummy variable equal to one if the plant reported a violation as a dependent variable. Violations were defined with respect to the laxer standards during the Pollution Reduction Plan.

The violation equation has the same explanatory variables as the BOD5 equation, but it has fewer observations. Five plants were dropped from the sample because they release effluents into the soil and there are no standards set for BOD5 in this case. Also, fourteen additional plants that complied or did not comply in every month of the period and therefore did not add any likelihood to the conditional model were also dropped from the sample.

7. RESULTS

I first present the results of the under-reporting tests. Then I turn to the discussion of the results of the inspection equations estimated for the IMM, DCA and SEINCO. Finally, I present the results of the BOD_5, Load and Violations equations.

7.1 UNDER-REPORTING TESTS

The first natural question that arises regarding the presence or absence of under-reporting is if there is any statistically significant difference between the means of the BOD_5 levels sampled by the IMM, DCA, and SEINCO. In order to answer this question, I conducted two difference-of-means tests. The first uses all available observations for each of the three series and the second uses the common sample (composed only by 5 observations). Forty-one plants were inspected by the three institutions. The results of the tests are presented in Table 7. According to the value of the ANOVA F-statistics, both the individual-sample and the common-sample tests suggest not rejecting the null of equal means.[35]

Based on the results of these tests, I construct a "pooled" BOD_5 sampled series with the IMM, DCA and SEINCO series. The pooled series (BOD_5SAMPLED) consist of the value of any of the three series, when only one is observed, or the average, when more than one is observed. After generating BOD_5SAMPLED, I conduct a test comparing its mean with the mean of the reported BOD_5. The result of this test is presented in Table 8. The value of the t-statistic (0.16) strongly suggests not rejecting the null of equal means between the reports and the samples.

35 The same result is obtained when taking any pair of the three series.

Table 7: Tests for Equality of Means between BOD_5IMM, BOD_5DCA and BOD_5SEINCO

Sample: 1997:07 2001:10

	Individual Samples		Common Sample	
Variable	Obs.	Mean	Obs.	Mean
BOD_5IMM	212	1395.8	5	1466.0
BOD_5DCA	114	1165.0	5	1784.2
BOD5SEINCO	408	1267.9	5	1166.0
All	734	1288.8	15	1472.1
	Anova F-statistic (2, 731)		Anova F-statistic (2, 12)	
	Value	Probability	Value	Probability
	0.27	0.7622	0.32	0.7323

Table 8: Tests for Equality of Means between the sampled BOD_5 (BOD_5SAMPLED) and the reported BOD_5 (BOD_5REP)

Sample: 1997:07 2001:10

Individual Samples		
Variable	Obs.	Mean
BOD_5SAMPLED	653	1343.2
BOD_5REP	1624	1363.1
All	2277	1357.4
t-test		
Degrees of freedom	Value	Probability
(2275)	0.16	0.8701

The previous tests suggest the absence of under-reporting on average. However, this is a wrong conclusion according to the tests that follow, which compare the means of the reported levels of the plants during the months in which they were not inspected and the months in which they were inspected. These tests are presented in Table 9. The last rows show the results when I pool the three inspecting institutions, while the rest of the rows present the results separately. The results show that, first, plants do not report different levels of BOD_5 to the IMM on average when they are inspected as compared to when they are not inspected by the IMM. Similarly, inspections of the DCA do not affect the average levels reported (to the IMM). Finally, the plants did report on average larger levels of BOD_5 to the IMM when they were sampled by SEINCO as compared to when they were not.

Table 9

Tests for Equality of Means between reported levels of BOD_5 (BOD_5REP) when inspected and when not inspected

Sample: 1997:07 2001:10

	Obs	BOD5REP Mean	Anova F-statistic df	Value	Prob
IMM					
No inspected	2643	1011.6	(1,2894)	0,02913	0,957
Inspected	253	1004.4			
DCA					
No inspected	1552	1343.2	(1,1640)	0,1576	0,6914
Inspected	90	1448.6			
SEINCO					
No inspected	1095	765.4	(1,1635)	15,68	0,001
Inspected	542	1122.3			
All					
No inspected	1104	1292.7	(1,1622)	2.82	0.0931
Inspected	520	1512.6			

Of course, not all the plants behaved in the same way. Analyzing plant-by-plant data could draw a better picture about the existence of under-reporting. Using all available observations for each series, at the five percent significance level, the tests suggests rejecting the null of equal means for twenty-five (25) of the total seventy-four (74) plants. At the 10% significance level, the test suggests rejecting the null of equal means for thirty-one (31) plants.

In sum, the results of these tests suggest that under–reporting may be present. But it is impossible to reach specific conclusions about the under-reporting strategy of plants based only on these simple tests. The econometric results presented in the following sections explore this issue further.

7.2 INSPECTION EQUATIONS

In this section I present the results of the estimation of the inspection equations for each of the three different monitoring institutions. I do not present the unconditional logistic regressions, just the conditional (fixed-effects) logistic regressions.

7.2.1 IMM Inspection Equation

Results for the IMM Inspection Equation are presented in Table 10.

Table 10: IMM Inspection Equation

Conditional (Fixed-effects) Logistic Regression

Dependent Variable: INSPIMM

Variable	Coefficient	Std. Error	z-Statistic	Prob.
INSPIMMCUM	-0.2103	0.0652	-3.22	0.001
INSPIMMOTHERCUM	-0.0091	0.0034	-2.64	0.008
INSPSEINCOCUM	-0.1349	0.0404	-3.34	0.001
FINEDIMMCUM	0.9895	0.3626	2.73	0.006
VOL	-0.0016	0.0089	-0.18	0.860
RF	0.4235	0.1978	2.14	0.032
DURINGPLAN	-0.4457	0.1894	-2.35	0.019
1997-1998	1.9198	0.2020	9.51	0.000
STREAM	1.1500	0.7873	1.46	0.144
Number of Observations	3066	Log likelihood		-803.3
LR statistic (9 df)	170.6	Pseudo R2		0.096
Prob > chi2	0.000			

Notes:
One plant (42 obs) dropped due to all positive or all negative outcomes.
WOOL omitted due to no within-group variance.
TANNERY omitted due to no within-group variance.
PTY omitted due to no within-group variance.

The results of the conditional regression are as expected. First, the more inspections a plant received in the past twelve months the less is the probability of being inspected again in a given month, according to the negative sign of INSPIMMCUM. This sign reflects the sample-without-replacement inspection strategy.

Second, the larger the number of inspections received by the rest of the plants in the last twelve months (INSPIMMOTHERCUM), the lower is the probability of an inspection for a given plant. Given the existence of a sample without replacement strategy, the interpretation for this sign is given by budget constraints. Inspection campaigns are costly, not only because of the opportunity costs of inspectors, but also of vehicles, which are used for several other duties. For these reasons, if a plant is not inspected when inspectors go to a given part of the city, it is costly for them to go there again on the following days. Nevertheless, the value of the coefficient of INSPIMMOTHERCUM is low.

Third, the negative sign of INSPSEINCOCUM is explained because the IMM used SEINCO inspections as a substitute for their own. This is a natural result since one of the objectives of the Monitoring Program developed by SEINCO with the Inter American Development Bank funds was to develop a monitoring strategy for the IMM.

Fourth, both the size of the coefficient of VOL and its lack of significance suggest that the IMM inspectors did not react to the economic situation of the industrial sector as might have been expected. Moreover, and according to the DURINGPLAN coefficient, they increased monitoring frequency after the end of the Plan in January 2000, in the middle of a recession that had started at the end of 1999 and lasted until 2002. Reasonably, after giving them enough time to comply, the IMM started to monitor industrial plants more closely. In fact, six of the eleven fines that the IMM applied during the period were applied after the end of the Plan.

Fifth, reporting failures (RF) was one the most important determinants of inspections, as indicated by its coefficient. This result is consistent with what was just stated, that the IMM preferred monitoring over enforcement. Apart from the Plan itself, another interpretation for this strategy is the need to meet the goal of increasing compliance levels with emission standards in order to not lose the funds obtained from the Inter American Development Bank on which the sanitary system works depends.

Sixth, the 1997–1998 dummy coefficient has the expected sign and the largest value. It is also highly significant. The monitoring campaigns developed by the IMM and financed by the Inter American Development Bank during those months of 1997 and 1998 represented an important jump in the frequency of inspections.

Finally, the IMM does not target plants emitting directly to a water body differently from those emitting to the sewage system, according to the insignificant coefficient of STREAM. The coefficient is large, however.

7.2.2 DCA Inspection Equation

Results for the DCA inspection equation are presented in Table 11. The results are also consistent with a-priori expectations. First, after correcting for the special monitoring campaigns that took place in 1999 on the Carrasco stream (CARRASCO1999), I find that the larger the number of inspections performed by the DCA in the last twelve months (INSPDCACUM), the lower is the probability of being inspected in a given month. Second, the larger the number of inspections performed by the DCA on the rest of the plants (INSPDCAOTHERCUM) in the last twelve months, the lower is the probability of being inspected in a given month. Explanations of these negative signs are similar to those given in the IMM case. It is somewhat surprising, however, that the magnitude of the coefficients is smaller than those of the IMM, given that the DCA is in charge of the monitoring and enforcement of virtually all environmental regulations in the country. The result is explained by two facts, however. First, the DCA inspected only forty-two (42) plants instead of seventy-four (74). Second, some sort of targeting is possible in this case because a DCA inspection has the primary objective of checking if the production conditions under which the discharge permit was given to the plant were unchanged. Consequently, the DCA frequently asks for technical reports and minor changes to the treatment plants, all of which require follow up inspections.

The national government inspectors reacted more than the municipal inspectors to the economic situation of the firms according to the significant and positive effect of VOL. This result is consistent with the fact that it is the national government that is politically responsible for the economic policy, not the municipal government. In this sense, DCA officials could have received more pressure against inspecting and fining firms. It is also true that the national government does not have any commitment with the Inter American Development Bank regarding industrial pollution, as does the municipal government. Therefore, it could simply inspect less during recessions, as it seems to have done. Finally, the DCA inspectors did not target plants emitting directly into water streams as compared to those emitting to the sewage system, the same result that was obtained for the IMM.

Table 11: DCA Inspection Equation

Conditional (fixed - effects) Logistic Regression

Dependent Variable: INSPDCA

Variable	Coefficient	Std. Error	z-Statistic	Prob.
INSPDCACUM	-0.1546	0.0749	-2.07	0.039
INSPDCAOTHERCUM	-0.0166	0.0067	-2.45	0.014
EADCACUM	-0.0497	0.0831	-0.60	0.550
VOL	0.0460	0.0099	4.66	0.000
CARRASCO1999	3.3478	0.4206	7.96	0.000
STREAM	0.6426	0.7883	0.82	0.415
Number of Observations	3016	Log likelihood		-508.8
LR statistic (6 df)	90.24	Pseudo R2		0.0815
Prob > chi2	0.000			

Notes:
16 plants (832 obs.) dropped due to all positive or all negative outcomes.
WOOL omitted due to no within-group variability.
TANNERY omitted due to no within-group variability.

7.2.3 SEINCO Inspection Equation

Results for the SEINCO inspection equation are presented in Table 12. Some results are unexpected in this case. First, SEINCO did not take into account IMM past inspections to decide who and when to inspect, according to the sign and significance level of INSPIMMCUM. This should not be that surprising if we recall that SEINCO's job was to design a monitoring strategy for the IMM. Nevertheless, it is surprising that the cumulative number of past inspections of the DCA appears with a positive and statistically significant coefficient.[36] The result is peculiar because the Director of the SEINCO Monitoring Program declared in an interview during the field research conducted for this work that they had no communication at all with the DCA officials and they did not take into account past inspections of the DCA when deciding who or when to

36 At the same time, INSPSEINCOCUM was insignificant when included in the DCA regression.

inspect. According to the Director of SEINCO's Monitoring Program, this result could only be explained by the fact that both institutions were targeting the same plants.

In fact what SEINCO did was to inspect big polluters every month during 1999 and every three months during 2000 and 2001. The rest of the plants were inspected every quarter during 1999 and every six months during 2000 and 2001. This sample without replacement rule also explains the negative sign on the coefficient for INSPSEINCOCUM.

Finally, SEINCO did not consider emissions directly into a water body to be an important variable in the allocation of inspections across plants.

Table 12: SEINCO Inspection Equation

Conditional (fixed - effects) Logistic Regression

Dependent Variable: INSPSEINCO

Variable	Coefficient	Std. Error	z-Statistic	Prob.
INSPSEINCOCUM	-0.1320	0.0222	-5.92	0.000
INSPIMMCUM	-0.0533	0.0566	-0.94	0.346
INSPDCACUM	0.2825	0.0595	4.75	0.000
STREAM	-0.1906	1.2740	-0.15	0.881
Number of Observations	2130	Log likelihood		-1059.6
LR statistic (4 df)	60.04	Pseudo R2		0.0275
Prob > chi2	0.000			

Notes:
Three plants (90 obs.) dropped due to all positive or all negative outcomes.
WOOL omitted due to no within-group variance.
TANNERY omitted due to no within-group variance.
PTY omitted due to no within-group variance.

7.3 THE POLLUTION EQUATIONS

Using the three unconditional models of inspections I obtain the probabilities of being inspected by each of the three inspecting institutions. I call these probabilities PINSPIMM, PINSPDCA and PINSPSEINCO. As explained earlier, these probabilities of being inspected are used as explanatory variables in the pollution equations to control for the behavior of plants regarding possible future monitoring and enforcement actions.

7.3.1 The BOD_5 Equation

Results for the BOD_5 equation are presented in Table 13. In fact, I estimate two different equations. In the first one, Specification 1, I only allow the constant term to differ during and after the Pollution Reduction Plan. In the second one, Specification 2, I also allow the slopes of the probabilities of being inspected by the IMM, DCA and SEINCO to differ.

Table 13: BOD_5 Equation

Method: Least Squares (Fixed Effects)*
Sample: 1998:06 2001:10
Total panel (unbalanced) observations: 2792
Dependent Variable: LOG(BOD5)

	Specification 1		Specification 2	
Variable	Coefficient	(t-Statistic)**	Coefficient	(t-Statistic)**
C	-1.2941		-1.5054	
LOG(PQ)	-0.1389	(-0.5064)	-0.1245	(-0.4559)
LOG(LABOR)	0.7766	(5.7526)	0.7820	(5.8271)
LOG(WATER)	0.0642	(0.8770)	0.0731	(1.0224)
LOG(ENERGY)	0.3169	(3.5408)	0.3103	(3.5181)
LOG(FLOW)	-0.1871	(-2.1555)	-0.1866	(-2.1723)
TECH	-1.3997	(-4.7755)	-1.4352	(-4.9851)
PINSPIMM	-0.0281	(-0.1210)	3.0465	(4.3577)
PINSPDCA	-0.6418	(-2.6015)	-0.9010	(-1.1958)
PINSPSEINCO	-0.1165	(-0.9202)	-0.3247	(-2.1518)
INSPIMMCUM	0.0011	(0.0733)	-0.0251	(-1.6959)
INSPDCACUM	0.0468	(2.7857)	0.0395	(2.4233)
FINEDIMMCUM	0.0301	(0.2925)	-0.1830	(-1.6281)
EADCACUM	-0.0191	(-0.9795)	-0.0103	(-0.5337)
DURINGPLAN	0.1470	(2.8324)	0.3610	(4.1210)
PINSPIMM*DURINGPLAN			-3.1012	(-4.7253)
PINSPDCA*DURINGPLAN			0.4800	(0.7700)
PINSPSEINCO*DURINGPLAN			0.2953	(1.5979)
R^2	0.8837		0.8851	
Adjusted R^2	0.8800		0.8812	
S.E.R.	0.7204		0.7192	
F- statistic	236.22		231.09	
Mean dependent var	4.1875		4.1876	
S.D. dependent var	2.0794		2.0868	
Sum squared resid	1403.2		1397.0	
Durbin-Watson stat	2.0032		2.0047	

* Fixed-effects are not presented.

** The t-statistic is calculated using Arellano's robust standard errors (Arellano, 1987). These are calculated with the data transformed after subtracting the within-plant mean. This is the reason why I do not present the constant's robust standard error.

Since the purpose of this study is to assess the impact of the monitoring and enforcement activity of regulators on emissions' levels, I will start the discussion of the results by analyzing these coefficients.

The first thing to notice is that PINSPIMM does not have a statistically significant effect on the reported levels of BOD_5 in Specification 1. But when I allow not only the constant term but also the slope to differ during and after the Plan, I find practically no marginal effect of PINSPIMM on the level of BOD_5 during the Plan period, but I find a strong positive effect of PINSPIMM after the Plan. This positive effect means that the larger the threat of being inspected by the IMM in a given month after the plan, the larger the level of reported BOD_5 by the plant for that month. This result is more evidence in favor of the existence of under-reporting.

Recalling that plants always send their reports after the inspection has taken place, how does this effect work? First, it makes no sense to under-report BOD_5 levels in those months in which plants were inspected because the IMM has information on how they were performing during that month. Furthermore, when participating in inspections I witnessed some plants taking a sample at the same time as the IMM to use it for control. Given that sampling is costly (i.e., it is costly to send the sample to a laboratory to obtain the results) it is very possible that the results obtained in this control sample are the same results that the plants report later to the IMM. Second, if a plant manager wants to under-report, it will be easier for him to convince the engineer in charge of the treatment plant to under-report by sampling effluents in moments in which pollution levels are lower, or even to dilute them, than to lie on the results of a more representative effluents' sample sent to an external laboratory. In this case the engineer in charge of the treatment plant will be taking a considerable risk because he is the one who is legally responsible for the truthfulness of the reports and it would be very easy for the IMM to check for the truthfulness of the reported levels of BOD_5 by asking him for the original results sent by the laboratory. Given this, if a plant manager perceives that the probability of being inspected is high in a given month, he will probably wait during the first days of the month to see if the inspection takes place. If it does take place, he can sample at the same time than the IMM for control and inform these results, which are going to be higher than the usual ones assuming it under-reports in general, that the IMM samples correctly and that the inspection does not take place in a moment of low pollution. If the inspection does not take place in the first days of the month, still perceiving a high probability of being inspected, the plant manager can take a representative sample of its effluents and send it to a laboratory. If the inspection finally takes place, results are going to be consistent with what the IMM founds. If it does not take place, given that sampling is costly, he will report the results of the representative sample sent to the laboratory.

Another important result is that neither the cumulative number of past inspections (INSPIMMCUM) nor the cumulative number of past fines (FINEDIMMCUM) in the last twelve months has an economically or statistically significant effect on present reported BOD_5 levels in any of the two specifications.

Third, the probability of being inspected by the DCA (PINSPDCA) has a negative effect on the reported levels of BOD_5. However, this effect is not statistically different from zero when I allow it to differ during and after the Pollution Reduction Plan. The negative sign in the first specification is explained because the inspections of the DCA are more predictable. The DCA always inspects after asking for technical reports or changes in the treatment plant, or after a special pollution incident. Although its coefficient is small, the positive sign of the cumulative number of inspections of the DCA (INSPDCACUM) is explained because of DCA's targeting strategy, in which case the coefficient would be given by differences across plants. With respect to DCA's enforcement actions in the last twelve months (EADCACUM), they do not have also a significant effect, economically and statistically, on BOD_5 levels in any of the two specifications.

Finally, the probability of being inspected by SEINCO (PINSPSEINCO) does not have an effect statistically different from zero in the first equation. However, although the coefficient during the Plan is close to zero, PINSPSEINCO has a negative effect on the reported levels of BOD_5 after the Plan in the second specification of the equation. It is interesting to note that this is exactly the opposite effect of a larger probability of being inspected by the IMM. Recalling that the IMM used SEINCO inspections as substitutes for their own, a reasonable explanation for this is that a larger probability of being inspected by SEINCO also meant a lower probability of being inspected by the IMM and therefore, a larger incentive to under-report. Of course, this explanation requires assuming that plants did not believe that the IMM inspectors would use SEINCO information to check for the truthfulness of the reports. It is difficult to explain reasons why the plants may have guessed correctly, but in fact it is possible that the IMM inspectors did not do this. In part it may have been because of the way in which SEINCO presented the information to the IMM, which was unprocessed and not easy to read. But there is also another explanation. The IMM inspectors may have felt a certain professional jealousy given the differences in their salaries and the costs of the Monitoring Program. In fact, during my field work I saw IMM inspectors checking for the consistency of the SEINCO information through time, in order to discover possible repetitions that could suggest that SEINCO did not actually inspect the plants, but I never saw them comparing the SEINCO samples with the plants' reports.

Another interesting result is the negative coefficient estimate of FLOW in both specifications. There is no a-priori reason why, ceteris paribus, plants with larger flows should have less BOD_5 concentration levels, except that the largest industries may also be those with the best treatment plants. But if this is not exactly the case, a negative sign of the FLOW coefficient could be saying that diluting is taking place. Although explicitly prohibited by law, diluting is an easy and cheap compliance strategy and at the same time very difficult to detect. The very low and insignificant coefficient on WATER in both specifications is consistent with this interpretation because it could be the result of two offsetting effects. On the one hand, water is a complement of pollution in production, but on the other it is a substitute for BOD_5 concentration levels if diluting takes place.

Not surprisingly, TECH appears with a strong negative sign in both specifications. In fact, it has the second largest coefficient after the reporting effect of PINSPIMM after the Plan. This raises the possibility that despite not being effective on the margin, monitoring and enforcement activities of the IMM and the DCA could have played a significant role in technology adoption. In fact, this is commonly the argument that IMM officials raise to explain the decline in average levels of reported pollution through time. This argument is backed up by the results of some simple regressions of TECH against the cumulative number of monitoring and enforcement actions taken by the IMM and the DCA during the period.[37] However, this explanation runs into some problems. First, only eight plants adopted technology during the period. Second, there were also other determinants for technology adoption, like emissions' treatment requirements from abroad in the case of international or exporting firms, that were not included in the auxiliary regressions conducted for TECH. Third, not controlling for technology adoption during the period did not change the mostly small and statistically insignificant coefficients of the monitoring and enforcement variables.

The remaining input variables (LABOR and ENERGY) have the expected signs and significance levels in both specifications. On the other hand, the output price coefficient (PQ) is negative. This may be the result of the market power of most firms in the sample because if firms do not operate in competitive markets, an increase in production levels, accompanied by an increase in pollution levels, has a negative effect on the price.

Finally, according to the sign of DURINGPLAN, the Pollution Reduction Plan was successful in reducing reported BOD_5 concentrations in industrial effluents. The explanation given by IMM inspectors for this result 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 explanation is difficult to accept when guided by the classical enforcement literature because expected fines were small. But it has already been recognized in the literature that compliance levels cannot be explained simply by expected fines.

7.3.2 The Load Equation

There is an ongoing debate in the country whether legislation should turn toward the regulation of loads instead of concentrations. Given this debate, it is interesting to test whether there is a difference in the effectiveness of the enforcement actions of the Uruguayan authorities in controlling loads with respect to concentrations. Given that coefficient estimates cannot be compared, by running this equation I am basically

37 The correlation coefficient between TECH and INSPIMMCUM, and TECH and INSPDCACUM is 0.05 and 0.03, respectively, which is very low. Therefore, multicollinearity is not an issue in the BOD5 equation.

searching for differences in the signs of the coefficients. Table 4 presents the results of a regression performed with LOAD = FLOW*BOD_5 as the dependent variable.

Table 14: Load Equation

Method: Least Squares (Fixed Effects)*
Sample: 1998:06 2001:10
Total panel (unbalanced) observations: 2794
Dependent Variable: LOG(LOAD)

	Specification 1		Specification 2	
Variable	Coefficient	(t-Statistic)**	Coefficient	(t-Statistic)**
C	0.4511		0.0592	
LOG(PQ)	-0.3125	(-1.1249)	-0.2679	(-0.9524)
LOG(LABOR)	0.6789	(4.3408)	0.6860	(4.4003)
LOG(WATER)	0.3669	(2.8332)	0.3670	(2.8694)
LOG(ENERGY)	0.3850	(5.1197)	0.3803	(5.1253)
TECH	-1.3380	(-3.4609)	-1.3861	(-3.4862)
PINSPIMM	0.2389	(0.7315)	3.8043	(3.5541)
PINSPDCA	-1.6609	(-2.4222)	-1.5348	(-1.3761)
PINSPSEINCO	-0.0954	(-0.6616)	-0.2054	(-1.0188)
INSPIMMCUM	0.0093	(0.4819)	-0.0196	(-0.9849)
INSPDCACUM	0.0581	(2.2261)	0.0482	(1.9514)
FINEDIMMCUM	0.0735	(0.3695)	-0.1302	(-0.6073)
EADCACUM	-0.0341	(-1.4149)	-0.0270	(-1.1297)
DURINGPLAN	0.1802	(2.3525)	0.5087	(3.4795)
PINSPIMM*DURINGPLAN			-3.6190	(-3.7710)
PINSPDCA*DURINGPLAN			0.1747	(0.1861)
PINSPSEINCO*DURINGPLAN			0.0984	(0.3815)
R^2	0.9318		0.9318	
Adjusted R^2	0.9296		0.9296	
S.E.R.	0.8742		0.8735	
F- statistic	429.78		415.38	
Mean dependent var	6.5688		6.5610	
S.D. dependent var	3.2944		3.2920	
Sum squared resid	2068.6		2063.0	
Durbin-Watson stat	1.9989		1.9966	

* Fixed-effects are not presented.

** The t-statistic is calculated using Arellano's robust standard errors (Arellano, 1987). These are calculated with the data transformed after subtracting the within-plant mean. This is the reason why I do not present the constant's robust standard error.

Except for the fact that the coefficients necessarily change magnitudes due to the change in the variation of the dependent variable, there are only two significant changes regarding the effect of each of the variables on LOAD as compared to BOD_5. One is the coefficient on WATER, which becomes statistically significant in both specifications. This is a natural result not necessarily suggesting any strategic behavior on the part of the firms. A second change is that PINSPSEINCO becomes insignificant after the Plan. The strategic behavior described in the last section regarding the reports of BOD_5 concentrations does not seem to operate with respect to loads. This may be explained because standards do not limit flows, so plants do not need to worry about them.

Finally, according to the sign of DURINGPLAN, the Pollution Reduction Plan was successful in reducing BOD_5 loads. The problem with this interpretation is that the period after-the-Plan coincided with a deep recession of the Uruguayan economy. This recession started in 1999 and ended in 2003, while the Plan ended in December 1999. Therefore, if we consider that a recession is commonly defined as three consecutive falls in the quarterly GDP, then the after-Plan period coincides almost exactly with the recession period. In other words, the recession could be the explanation for the fall in the levels of BOD_5, not the Plan. This may be true, even after considering that LABOR and ENERGY indirectly correct for part of the effect of the recession on BOD_5 levels.

7.3.3 The Violation Equation

My main objective in this section is to answer the question "Do enforcement actions affect the probability of a violation?" In order to do so I define my dependent variable as a dummy variable equal to one if the plant reported a violation. Violation is defined with respect to the laxer standards during the Pollution Reduction Plan. Results are presented in Table 15. This model discards four hundreds and eighty three (483) observations belonging to fourteen (14) plants that either complied or did not comply in every month, and therefore did not add any likelihood to the conditional model. Leaving aside plants that did not change their compliance status during the whole period, with violation being the most common status, obviously biases upward the effectiveness of the monitoring and enforcement variables. Therefore, the results should be interpreted while taking this into account.

The most striking result is the statistical insignificance of all the monitoring and enforcement variables in the first specification of the model, when only the intercept is allowed to vary between during-Plan and after-Plan periods. The only variable that appears to have an effect on the violation status of firms in this first specification is the probability of being inspected by the DCA. Although this variable is not significant even at a 10% level, it has a very large coefficient.

Table 15: Violation Equation

Method: Conditional (Fixed Effects) Logit
Sample: 1998:06 2001:10
Total panel (unbalanced) observations: 2008
Dependent Variable: VIOL

	Specification 1		Specification 2	
Variable	Coefficient	(z-Statistic)	Coefficient	(z-Statistic)
LOG(PQ)	-1.1203	(-1.27)	-1.2597	-1.42
LOG(LABOR)	0.1382	(0.67)	0.1699	0.81
LOG(WATER)	0.3127	(2.48)	0.3244	2.56
LOG(ENERGY)	0.8942	(4.46)	0.8214	4.03
LOG(FLOW)	-0.7346	(-6.03)	-0.7067	-5.80
TECH	-3.2750	(-5.38)	-3.6495	-5.96
PINSPIMM	-0.3943	(-0.37)	9.2874	2.48
PINSPDCA	-2.4451	(-1.32)	7.1042	1.68
PINSPSEINCO	0.3375	(0.66)	0.3408	0.52
INSPIMMCUM	-0.0065	(-0.09)	-0.1412	-1.61
INSPDCACUM	-0.0223	(-0.27)	-0.0934	-1.08
FINEDIMMCUM	-0.1158	(-0.22)	-0.9292	-1.57
EADCACUM	-0.0616	(-0.76)	-0.0186	-0.22
DURINGPLAN	-1.1734	(-6.64)	0.3356	0.77
PINSPIMM*DURINGPLAN			-10.248	-2.71
PINSPDCA*DURINGPLAN			-10.448	-2.29
PINSPSEINCO*DURINGPLAN			-0.5128	-0.56
Pseudo R^2	0.1072		0.1193	
LR chi2(14)	168.11		187.08	
Prob > chi2	0.000		0.000	
Log likelihood	-700.2		-690.7	

The rest of the coefficients in the first specification have the expected signs and significance levels, except for the LABOR coefficient, which is insignificant. Apart from PINSPDCA, the variables with larger effects on the compliance status of plants are TECH, DURINGPLAN, PQ and FLOW. According to the significance level and magnitude of its coefficient, abatement technology adoption is clearly a determinant factor of the compliance status of plants. 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 BOD_5 and LOAD levels). The size of the coefficient of PQ is also interesting because it says that, ceteris paribus, the more the revenues of the plants, the less is the probability of being in violation. Finally, the coefficient on FLOW raises the issue again about the possibility of diluting as a compliance strategy versus the possibility that larger plants are the ones with the best treatment plants.

As was the case for the BOD_5 and LOAD equations, Table 15 also presents the results of the violation equation after including interaction effects between the DURINGPLAN dummy and the three probabilities. In sum, the inclusion of interaction effects does not change the magnitudes and significance levels of the estimates of the input variables and PINSPSEINCO, but it does change the coefficient estimates of the IMM and DCA monitoring and enforcement variables. PINSPIMM turned significant, negatively affecting the probability of violating during the Plan, but with a positive and very large coefficient after the end of the Plan. This is consistent with the BOD_5 and LOAD equations. Another difference is the increase in the significance levels of the cumulative number of past inspections (INSPIMMCUM) and fines (FINEDIMMCUM) performed by the IMM. Nevertheless, one has to take into account the caveat at the beginning of this section: plants included in this regression are those that changed compliance status during the period at least once. With the violation status being a common case through time and across plants, the results of the effectiveness of the monitoring and enforcement variables are biased upward.

The conclusions are similar for the case of the DCA. The probability of being inspected by the DCA (PINSPDCA) has a very large coefficient after the plan, although it is not significant at a 5% level. During the Plan, on the other hand, PINSPDCA negatively affects the probability of being in compliance, according to the sum of the coefficients of PINSPDCA and PINSPDCA*DURINGPLAN. (The sum of these coefficients is statistically different from zero). The cumulative number of past inspections (INSPDCACUM) and intermediate enforcement actions (EADCACUM) remained insignificant after including the interaction effects.

Finally, and very interestingly, with the inclusion of interaction effects the DURINGPLAN dummy becomes insignificant. This result says that the Plan did not have any effect on the compliance status of firms. The result is extremely important because the increase in the levels of compliance of industrial firms with effluent standards was the main objective of the program undertaken by the IMM with funds from the Inter American Development Bank. According to this result, the program failed to do this.

8. CONCLUSIONS

The general conclusions that can be derived from these estimations are the following. The municipal government (IMM) monitoring and enforcement activity did not have an important deterrent effect on reported BOD_5 levels. However, I find that the larger the threat of being inspected by the IMM in a given month after the plan, the larger the level of reported BOD_5 by the plant for that month. This result is consistent with some results of the difference of means tests, which suggested the presence of under-reporting. The result is also important because it suggests that IMM inspections were an effective way of discovering unreported violations. Of course uncovering violations is not enough to increase compliance. Uncovered violations need to be punished. But the number of fines applied by the IMM during the period clearly suggests that regulators were not willing to impose them. As a potential consequence, despite the effectiveness that the threat of an inspection had on the reported levels of pollution in subsequent months, the cumulative number of past fines did not have any effect on the levels of BOD_5.

The national government (DCA) monitoring and enforcement activity was not clearly effective in deterring reported BOD_5 levels. Also, plants used the inspections of the private consortium SEINCO to under-report to the IMM.

Another important result is that diluting may have taken place. Although explicitly prohibited by law, diluting is an easy and cheap compliance strategy and at the same time very difficult to detect.

Abatement technology adoption is a very important explanatory variable. This is not very surprising but it raises the possibility that despite not being effective on the margin, monitoring and enforcement activities of the IMM and the DCA could have played a significant role in technology adoption. However, only eight plants adopted technology during the period, and there are also other determinants for technology adoption, like effluents treatment requirements from abroad in the case of international or exporting firms.

The Pollution Reduction Plan may have been successful in reducing BOD_5 concentration levels of emissions and BOD_5 loads. An alternative interpretation is that the period after-the-Plan coincided with a deep recession in the Uruguayan economy and the recession could be the explanation for the fall in pollution, not the Plan.

When repeating the estimation with loads of BOD_5 as the dependent variable, as opposed to concentration levels, I found no significant differences in the signs or significance levels of estimated coefficients.

Finally, the performance of the Uruguayan enforcers did not have any effect on the compliance status of industrial plants. The only exception is that the probability of being inspected by the IMM negatively affected the probability of reported violations during the Plan, but positively affected it after the end of the Plan. This result is consistent with the previous result that the threats of an inspection reduced reported BOD_5. The variables with larger effects on the compliance status of plants are technology adoption, the price of the output and the effluent flow. The effect of effluents flow raises again the possibility of diluting as a compliance strategy versus the possibility that larger plants are the ones with best treatment plants. However, one has to take into account that, because of the estimation technique, plants included in this regression are those that changed compliance status during the period. With frequent violations this biases upward the effectiveness of the monitoring and enforcement variables. Finally, the Pollution Reduction Plan had a positive effect on compliance levels according to the first specification of the equation, but with the inclusion of interaction effects this disappears. The simplest explanation for the positive effect on the first specification is that during the Plan emission standards were laxer, outweighing the fact that emissions were also larger during the Plan. The results are important because the increase in the levels of compliance of industrial firms with effluent standards was the main objective of the program undertaken by the IMM with funds from the Inter American Development Bank. According to these results, the program failed to accomplish this.

APPENDIX : DEFINITIONS OF VARIABLES

Table A.1

Name	Definition
1997-1998	Dummy equal to one in months of 1997 and 1998 during which the IMM conducted special, IADB-financed monitoring campaigns
$BOD5_{i,t}$ =	Biological Oxygen Demand concentration of discharges, in mg/l
$CARRASCO1999_{i,t}$=	Dummy equal to one in the months of 199 during which the DCA conducted a special monitoring campaign in the Carrasco stream
$DURINGPLAN_t$=	Dummy equal to one during the Industrial Pollution Reduction Plan months
$ENERGY_{i,t}$ =	Total energy consumption in mega joules (MJ)
$EADCACUM_{i,t}$=	Number of enforcement actions (orders and fines) imposed by the DCA against the plant in the last twelve months
$FLOW_{i,t}$ =	Daily average effluent flow (m3/day)
$INSPDCA_{i,t}$ =	Dummy equal to one if plant *i* was inspected by the DCA in month *t*
$INSPDCACUM_{i,t-1}$=	Number of inspections performed by the DCA in the plant during the last twelve months
$INSPDCAOTHERCUM_{i,t-1}$=	Number of inspections performed by the DCA in the rest of the plants during the last twelve months
$INSPIMM_{i,t}$ =	Dummy equal to one if plant *i* was inspected by the IMM in month *t*
$INSPIMMCUM_{i,t-1}$=	Number of inspections performed by the IMM in the plant during the last twelve months
$INSPIMMOTHERCUM_{i,t-1}$=	Number of inspections performed by the IMM in the rest of the plants during the last twelve months
$INSPSEINCO_{i,t}$=	Dummy equal to one if plant *i* was inspected by SEINCO in month *t*
$INSPSEINCOCUM_{i,t-1}$=	Number of inspections performed by SEINCO in the plant during the last twelve months
$FINEDIMMCUM_{i,t-1}$=	Number of fines imposed by the IMM against the plant in the last twelve months
$LABOR_{i,t}$ =	Total days-employee worked
$LOAD_{i,t}$ =	*(BOD5*FLOW)* = Total organic pollution discharged in (mg/day)
$PINSPIMM_{i,t}$ =	Probability of being inspected by the IMM
$PINSPDCA_{i,t}$ =	Probability of being inspected by the DCA
$PINSPSEINCO_{i,t}$ =	Probability of being inspected by SEINCO
$P_{q,t}$=	Price of the good produced
PTY_i=	Dummy equal to 1 if the plant is a Priority 1 plant
$RF_{i,t}$ =	The number of reporting failures in the previous two reporting periods
$STREAM_{i,t}$=	Dummy equal to one if the plant emits directly into a water body
$TANNERY_i$=	Dummy equal to one if the plant is a tannery
$TECH_{i,t}$ =	Dummy equal to one after plant modified their treatment plants
$VIOL_{i,t}$ =	Dummy equal to one if the plant reported a violation
VOL_t =	Monthly level of the industry production volume index
$WATER_{i,t}$ =	Total water consumption in m3/month
$WOOL_i$=	Dummy equal to one if the plant is a wool washer

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