CHAPTER 8

RESULTS AND DISCUSSION

The objective of this chapter is to present the estimation results of the equations presented in Chapter 7. The first part of the chapter is devoted to the exposition and discussion of the results of the tests conducted to explore the existence of under-reporting. A unique feature of this dissertation 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 IMM, a third is the level sampled by the DCA and the fourth is the level sampled by SEINCO. This unique feature allows me to perform difference of means tests as a simple way to explore the presence or absence of under-reporting.

I then turn to the discussion of the results of the inspection equations estimated for the IMM, DCA and SEINCO, as discussed in Chapter 7. These equations allow identifying the determinants of the inspection strategy each of the three inspecting institutions.

Finally, I present the main econometric results of my dissertation. These are given by the estimates of the BOD_5 equation, the LOAD equation and the Violation equation. Three of these equations share the main objective of identifying the most important determinants of pollution in the industrial sector of Montevideo, paying special attention to the effects of the monitoring and enforcement activities of each of the three institutions that conducted inspections during the study period, July 1997 – October 2001.

8.1 UNDER-REPORTING TESTS

As said, the availability of four sources of information regarding the levels of BOD_5 emitted by plants allows me to perform simple difference of means tests to explore the existence of under-reporting. These four sources are the BOD_5 levels reported by the plants to the IMM and the results of the inspection samples taken by the IMM, DCA and SEINCO.

The first natural question that arises 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 8.1. 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.[69]

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

[69] The same result is obtained when taking any pair of the three series.

presented in Table 8.2. The value of the t-statistic (0.16) strongly suggests not rejecting the null of equal means between the reports and the samples.

Table 8.1.

Tests for Equality of Means between BOD_5IMM, BOD_5DCA and $BOD_5SEINCO$

Sample: 1997:07 2001:10

Individual Samples		
Variable	Obs.	Mean
BOD_5IMM	212	1395.8
BOD_5DCA	114	1165.0
$BOD_5SEINCO$	408	1267.9
All	734	1288.8
Anova F-statistic		
Degrees of freedom	Value	Probability
(2, 731)	0.27	0.7622
Common Sample		
Variable	Obs.	Mean
BOD_5IMM	5	1466.0
BOD_5DCA	5	1784.2
$BOD_5SEINCO$	5	1166.0
All	15	1472.1
Anova F-statistic		
Degrees of freedom	Value	Probability
(2, 12)	0.32	0.7323

Table 8.2.

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. 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 8.3. 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 8.3

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	df	Anova F-statistic 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. This is done in Appendix Table A.8.1. This table presents the ANOVA F-statistics and their probabilities for the equality of means between BOD_5REP, BOD_5IMM, BOD_5DCA and BOD_5SEINCO for each of the seventy-four plants in the sample. The tests are performed using all available observations for each series. At the five percent significance level, the test 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.

8.2 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 present both the unconditional and the conditional (fixed-effects) logistic regressions. The first technique allows me to fit a probability of inspection to be used later in the pollution equation, as explained in Chapter 7. The second technique, although it does not allow me to fit a similar probability because it does not estimate the fixed effects, acknowledges that my estimates of the unconditional equation may be inconsistent a priori because I do not use plant-specific effects to control for plant heterogeneity. Consequently, it is only with the results of the conditional regression that I base the interpretations of the coefficient estimates.

8.2.1 IMM Inspection Equation

Results for the IMM Inspection Equation are presented in Tables 8.4(a) and (b). Table 8.4(a) presents the results for the unconditional logistic regression and Table 8.4(b) presents the results for the conditional (fixed-effects) logistic regression.

Table 8.4(a)

IMM Inspection Equation

Unconditional Logistic Regression

Dependent Variable: INSPIMM

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-1.5124	0.9613	-1.5733	0.1156
INSPIMMCUM	0.1619	0.0492	3.2919	0.0010
INSPIMMOTHERCUM	-0.0107	0.0032	-3.2946	0.0010
INSPSEINCOCUM	-0.0515	0.0339	-1.5205	0.1284
FINEDIMMCUM	0.6761	0.2616	2.5846	0.0097
VOL	-0.0019	0.0089	-0.2119	0.8322
RF	0.1820	0.1440	1.2637	0.2063
PTY	0.3026	0.1394	2.1706	0.0300
TANNERY	0.4802	0.1505	3.1902	0.0014
WOOL	0.4633	0.2781	1.6658	0.0958
1997-1998	1.9444	0.1978	9.8292	0.0000
DURINGPLAN	-0.3760	0.1861	-2.0203	0.0433
STREAM	0.0221	0.1386	0.1594	0.8733

Mean dependent var	0.1088	S.D. dependent var	0.3114
S.E. of regression	0.3008	Akaike info criterion	0.6366
Sum squared resid	280.07	Schwarz criterion	0.6618
Log likelihood	-975.80	Hannan-Quinn criter.	0.6456
Restr. log likelihood	-1068.8	Avg. log likelihood	-0.3141
LR statistic (12 df)	186.06	McFadden R-squared	0.0866
Probability(LR stat)	0.0000		
Obs with Dep=0	2770	Number of observations	3108
Obs with Dep=1	338		

Table 8.4(b)

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 because of coordination costs. In order to go out on inspection inspectors at the IMM need to ask for a vehicle, which is not used exclusively by the industrial effluents unit. This means that the vehicle is not physically in the same building as the inspectors, and also that it has its own opportunity costs because it is used for several other duties. As a result, inspectors often wait a significant amount of time for the vehicle to arrive. 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, the IMM applied only eleven fines during the period despite frequent violations. But six of these fines were applied after the end of the Plan. The rest were at the beginning, possibly the result of violations that occurred before the Plan. In conclusion, the IMM policy approach during the Pollution Reduction Plan was not to fine plants.

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 coefficient. 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 were an important break in the frequency of inspections This is clearly observable in Figure 2.2 of Chapter 2.

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.

8.2.2 DCA Inspection Equation

Results for the DCA inspection equation are presented in Tables 8.5 (a) and (b). Table 8.5(a) presents the results for the unconditional logistic regression and Table 8.5(b) presents the results for the conditional (fixed effects) regression.

The fixed-effects regression results are also consistent with 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). Therefore, the effect of the sample without replacement strategy on the probability of being inspected is less because there are less firms to inspect. 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 8.5(a)

DCA Inspection Equation

Unconditional Logistic Regression

Dependent Variable: INSPDCA

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-7.3831	1.0589	-6.9725	0.0000
INDPDCACUM	0.1476	0.0616	2.3953	0.0166
INSPDCAOTHERCUM	-0.0256	0.0068	-3.7653	0.0002
EADCACUM	0.1108	0.0754	1.4707	0.1414
TANNERY	0.0447	0.0097	4.6259	0.0000
WOOL	0.7389	0.1939	3.8107	0.0001
VOL	1.2101	0.2902	4.1698	0.0000
CARRASCO1999	2.8095	0.3212	8.7467	0.0000
STREAM	0.5256	0.1897	2.7708	0.0056

Mean dependent var	0.0483	S.D. dependent var	0.2145
S.E. of regression	0.2061	Akaike info criterion	0.3438
Sum squared resid	163.1	Schwarz criterion	0.3584
Log likelihood	-652.4	Hannan-Quinn criter.	0.3490
Restr. log likelihood	-744.9	Avg. log likelihood	-0.1695
LR statistic (12 df)	185.1	McFadden R-squared	0.1242
Probability(LR stat)	0.00		
Obs with Dep=0	3662	Number of observations	3848
Obs with Dep=1	186		

Table 8.5(b)

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.

8.2.3 SEINCO Inspection Equation

Results for the SEINCO inspection equation are presented in Tables 8.6(a) and (b) in the same way as the IMM and the DCA results. The fixed-effects regression in this case provides some unexpected results. First, SEINCO seems not to have taken 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.[70] The result is peculiar because the

[70] At the same time, INSPSEINCOCUM was insignificant when included in the DCA regression.

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 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 8.6(a)

SEINCO Inspection Equation

Unconditional Logistic Regression

Dependent Variable: INSPDCA

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-1.8654	0.1049	-17.7769	0.0000
INSPSEINCOCUM	0.2106	0.0193	10.9150	0.0000
INSPIMMTOTCUM	0.0322	0.0428	0.7532	0.4513
INSPDCATOTCUM	0.1415	0.0384	3.6887	0.0002
PTY	0.4662	0.1101	4.2336	0.0000
TANNERY	-0.2061	0.1422	-1.4494	0.1472
WOOL	-0.1069	0.2519	-0.4241	0.6715
STREAM	0.0121	0.1101	0.1096	0.9127
Mean dependent var	0.2986	S.D. dependent var		0.4578
S.E. of regression	0.4379	Akaike info criterion		1.1309
Sum squared resid	424.19	Schwarz criterion		1.1514
Log likelihood	-1247.3	Hannan-Quinn criter.		1.1384
Restr. log likelihood	-1353.6	Avg. log likelihood		-0.5618
LR statistic (12 df)	212.6	McFadden R-squared		0.0785
Probability(LR stat)	0.0000			
Obs with Dep=0	1557	Number of observations		2220
Obs with Dep=1	663			

Table 8.6(b)

SEINCO Inspection Equation

Conditional (fixed - effects) Logistic Regression

Dependent Variable: INSPDCA

Variable	Coefficient	Std. Error	z-Statistic	Prob.
INSOSEINCOCUM	-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.

8.3 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, respectively. As explained in Chapter 7, 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.

8.3.1 The BOD_5 Equation

In this subsection I present the results obtained for the BOD_5 equation discussed in Chapter 7. This equation seeks to determine what factors influence levels of emissions. Results are presented in Table 8.7. 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 8.7

BOD_5 Equation

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

Variable	Specification 1 Coefficient	Specification 1 (t-Statistic)**	Specification 2 Coefficient	Specification 2 (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. In other words, just the threat of an inspection seems to have an effect on plants' incentives to increase the reported levels of BOD_5. This result is more evidence in favor of the existence of under-reporting.

How does this effect work? First, recall that plants always send their reports after the inspection has taken place. Therefore, it makes no sense for them to under-report BOD_5 levels in those months in which they 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. In this setting, 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. This result 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 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, when I allow only the constant term to differ between the during and after-the-Plan periods. 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.[71] 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

[71] 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 BOD_5 equation.

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 are small. But past empirical studies usually indicate that compliance levels are larger than what theory would predict, given expected fines. Therefore, it has already been recognized that compliance levels cannot be explained simply by expected fines.

8.3.2 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 searching for differences in the signs of the coefficients.

Table 8.8 presents the results of a regression performed with LOAD = FLOW*BOD_5 (as opposed to BOD_5 as the dependent variable) as the dependent variable.

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.

Table 8.8

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.

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.

8.3.3 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 8.9. This model uses fewer observations because it 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. (See Annex to Chapter 7). 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.

Table 8.9

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 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.

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 8.6 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.

8.4 CONCLUSIONS

The objective of this chapter was to present the results of some simple tests for under-reporting and the estimation of the inspection, pollution and violation equations presented in Chapter 7. The inspection equations identify the determinants of the inspection strategy of each of the three institutions that conducted inspections during July 1997 – October 2001. The pollution and violation equations shared the main objective of identifying the most important determinants of pollution and compliance in the industrial sector of Montevideo, paying special attention to the effects of the inspections and the rest the enforcement actions of each of the aforementioned institutions.

The general conclusions that can be derived from these estimations are the following. IMM monitoring and enforcement activity did not have an important deterrent effect on reported BOD_5 levels. However, I find that the threat of an inspection had an effect on plants' reports of BOD_5. 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 during the last twelve months did not have any effect.

The DCA monitoring and enforcement activity was not clearly effective in deterring reported BOD_5 levels. Also, the clearest result of SEINCO activity is that the plants used their inspections to under-report to the IMM after they learned that the IMM used SEINCO inspections as substitutes for their own. This explanation requires assuming that plants believed that the IMM inspectors would not use SEINCO information to check for the truthfulness of the reports. I have evidence from the field that this is true.

Finally, the IMM inspectors did not react to the economic situation of the industrial sector by decreasing their inspections. To the contrary, they increased inspections after the Plan, exactly when the economy was in a recession. This monitoring strategy, apparently immune to political considerations, has another possible explanation: that the IMM regulators kept monitoring firms in order not to risk the funds from the Inter American Development Bank upon which the sanitary works in the city depend. The national government does not have such a commitment with a multilateral financing institution and is politically responsible for the performance of the economy. Therefore, it did react to the economic situation of the firms.

Another important result is that diluting may have taken place. The conclusion is based on the fact that there is no a-priori reason why, ceteris paribus, plants with larger flows should have less BOD_5 concentration levels, except for the possibility that the largest industrial plants may also be those with the best treatment plants. 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. In fact, this is the argument that IMM officials raise to explain the decline in average levels of reported pollution through time. However, this argument runs into some problems. First, only eight plants adopted technology during the period. Second, there are also other determinants for technology adoption, like effluents treatment requirements from abroad in the case of international or exporting firms.

Another important result is that 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 Pollution Reduction Plan, the price of the output and the effluent flow. The simplest explanation for the effect of the Pollution Reduction Plan on violation status of plants is that during the Plan emission standards were laxer, outweighing the fact that emissions were also larger during the Plan. The effect of the price of the output is also interesting because it is saying that, ceteris paribus, the more the revenues of the plants, the less is the probability of being in violation. Finally, the effect of effluents flow raises again the 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, and very interestingly, with the inclusion of interaction effects the Pollution Reduction Plan did not have any effect on the compliance status of firms. The result is 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 accomplish this.

APPENDIX 8.1

Table A.8.1

Plant-specific under-reporting tests

		Anova F-statistic		1=reject=underreporting	
Plant	df	Value	Probability	5%	10%
1	(2,26)	0.07	0.94	0	0
2	(2,58)	240.60	0.00	1	1
3	(2,60)	0.20	0.82	0	0
4	(2,46)	1.71	0.19	0	0
5	(3,28)	0.22	0.88	0	0
6	(2,58)	4.46	0.02	1	1
7	(2,29)	6.61	0.00	1	1
8	(2,59)	12.74	0.00	1	1
9	(3,75)	1.30	0.28	0	0
10	(2,51)	15.08	0.00	1	1
11	(3,64)	3.54	0.02	1	1
12	(3,56)	0.70	0.56	0	0
13	(3,33)	6.08	0.00	1	1
14	(2,43)	6.76	0.00	1	1
15	(3,61)	0.67	0.57	0	0
16	(3,77)	3.35	0.02	1	1
17	(3,59)	6.46	0.00	1	1
18	(3,57)	7.59	0.00	1	1
19	(3,63)	4.86	0.00	1	1
20	(2,31)	2.37	0.11	0	0
21	(3,63)	1.23	0.31	0	0
22	(3,58)	0.79	0.51	0	0
23	(3,71)	0.19	0.90	0	0
24	(3,58)	1.36	0.26	0	0
25	(2,39)	0.40	0.68	0	0
26	(2,39)	3.04	0.06	0	1
27	(3,52)	0.68	0.57	0	0
28	(3,65)	0.58	0.63	0	0
29	(3,22)	1.56	0.23	0	0
30	(2,57)	3.70	0.03	1	1
31	(2,58)	2.33	0.11	0	0
32	(3,67)	0.83	0.48	0	0
33	(3,60)	0.71	0.55	0	0
34	(3,72)	0.80	0.50	0	0
35	(3,60)	0.63	0.60	0	0
36	(2,20)	0.64	0.54	0	0
37	(3,38)	1.20	0.32	0	0
38	(2,33)	0.26	0.77	0	0
39	(3,27)	0.69	0.57	0	0
40	(3,32)	0.25	0.86	0	0
41	(3,28)	14.41	0.00	1	1
42	(3,56)	5.84	0.00	1	1

Table A.8.1 continued

43	(3,52)	0.33	0.80	0	0
44	(3,77)	2.39	0.07	0	1
45	(2,61)	0.41	0.67	0	0
46	(2,46)	0.95	0.39	0	0
47	(2,69)	7.08	0.00	1	1
48	(3,37)	0.91	0.44	0	0
49	(2,56)	3.47	0.04	1	1
50	(2,44)	3.78	0.03	1	1
51	(1,38)	59.53	0.00	1	1
52	(2,21)	0.24	0.79	0	0
53	(1,30)	5.10	0.03	1	1
54	(2,48)	0.23	0.80	0	0
55	(3,56)	0.78	0.51	0	0
56	(3,72)	4.09	0.01	1	1
57	(2,53)	1.12	0.33	0	0
58	(2,38)	3.00	0.06	0	1
59	(2,63)	0.84	0.44	0	0
60	(3,26)	2.61	0.07	0	1
61	(3,64)	0.66	0.58	0	0
62	(3,62)	3.13	0.03	1	1
63	(3,57)	3.56	0.02	1	1
64	(2,55)	3.12	0.05	0	1
65	(2,57)	0.86	0.43	0	0
66	(3,35)	1.02	0.40	0	0
67	(3,59)	2.25	0.09	0	1
68	(2,61)	62.61	0.00	1	1
69	(2,56)	0.36	0.70	0	0
70	(2,50)	0.48	0.62	0	0
71	(3,62)	1.55	0.21	0	0
72	(3,34)	2.06	0.12	0	0
73	(3,52)	1.13	0.35	0	0
74	(3,47)	7.38	0.00	1	1
Total				25	31
Percentage				33.78	41.89