FULL RESEARCH PROPOSAL – CAFFERA

Title of the Project: Testing the Effectiveness of Enforcing Industrial Pollution Regulations in Montevideo, Uruguay

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Abstract: The purpose of this project is to analyze the effect of the different enforcement measures taken by regulators and the levels of organic pollution of industrial plants (as measured by tons of BOD_5 of their effluents) in Montevideo, Uruguay, during the period 1997-2007. More specifically, the research aims to answer the following questions. (1) Has the enforcers' activity been sufficient to significantly improve industrial firms' levels of compliance with effluent standards under the new enforcement regime? (2) What characteristics of industrial plants are more correlated with higher levels of BOD_5 in effluents and non-compliance? In order to answer these questions I will use advanced econometric techniques to test the following hypothesis: An increase in expected penalties, defined as the probability of being inspected multiplied by the amount of the corresponding fine, decreases the probability that an industrial plant would be out of compliance with effluent standards

1. RESEARCH PROBLEM

In March 1997, Uruguayan enforcers of industrial emissions standards in Montevideo opted for a strategy based on frequent monitoring of industrial plants and some tolerance for non-compliance (a strategy called "compliance regime" by Garvie and Keeler (1994)), even with respect to relaxed emissions standards. This strategy was part of the "Industrial Pollution Reduction Plan", which gave firms almost two years to invest in abatement technology. (Caffera, 2004). By this way, regulators sought to decrease the levels of noncompliance of the city industrial plants with emissions standards. At the same time, one of the most severe economic crises in the country's history started in 1999, almost at the end of the Plan. As a result, regulators opted to continue being lenient with violators after the scheduled "grace period" ended. This strategy failed to improve compliance levels with BOD_5 emission standards. (Caffera, 2007). According to what regulators and inspectors declared in informal interviews and contacts I had with them over the last years, they have been applying another enforcement strategy since the crisis ended in 2003, and even more distinctively since the change in municipal authorities in 2005. This strategy is characterized by less tolerance for violations and more penalties applied (what Garvie and Keeler (1994) called a "deterrence regime"). The data substantiate what they say. On average, during the period 1997 – 2002, they applied around seven penalties per year. This number doubled during the years 2003 and 2007. Unluckily, we know nothing about how effective this new strategy has been in increasing the levels of compliance.

The objective of this research is to fill this gap in our knowledge. The focus is on providing answers to the following questions. (1) Has the enforcers' activity been sufficient to significantly improve industrial firms' levels of compliance with effluent standards under the new enforcement regime? (2) What characteristics of industrial plants are more correlated with higher levels of BOD_5 in effluents and non-compliance? The project will use a rich data set and advanced econometric techniques to provide the answers to these questions. Providing these answers is relevant to policy making. They will provide regulators with statistically rigorous information based on which to decide how to use their scarce enforcement budgets more effectively, by potentially re-allocating enforcement resources among industrial plants and/or activities (inspections, intermediate enforcement actions and fines). It will also be a rigorous test of the relative effectiveness of both approaches to regulation: lenient regime vs. less tolerant. This will be an important product of the project because regulators in less developed countries like Uruguay, with an important part of the population with unsatisfied basic needs, face important tradeoffs between the objectives of providing employment and protecting the environment. This tradeoff acts as an incentive to implement a lenient regime when industrial plants pressure regulators arguing that abating emissions threats them going out of business, with the consequence of jobs being lost.

In spite that several authors have acknowledged the lack of institutional capacity in less developed countries to enforce environmental regulations (see Eskeland and Jimenez, 1992; Tietenberg, 1996; Russell and Powell, 1996, O'Connor, 1998; Blackman, and Harrington, 2000)1, there is a large disparity in the number of comprehensive empirical studies analyzing the effectiveness of environmental regulators' enforcement activity in developed and less developed countries. To my knowledge, the only examples of published papers for a less developed country that use a comprehensive database on emissions and enforcement actions are Dasgupta et al. (2001), Wang et al. (2003) and Wang and Wheeler (2005). The studies done on Latin America are cross-section studies without information on either emissions (Blackman and Bannister (1998), Dasgupta, et al. (2000), Coronado (2001), Cruz and Uribe (2002), Ferraz, et al. (2003), Otero (2002), Gangadharan (2006)) or enforcement activities (Palacios and Chavez, (2005)). This gap constitutes an obstacle for the design of effective environmental policy in Latin America. If we environmental economists interested in development issues are to say something useful about how to organize environmental policy in these countries we need to conduct more applied research. Nevertheless, there is no work that uses time series data on emissions, inspections and fines on a Latin American country. Caffera (2007) may be an exception, but the studied period in that work was too special to draw general conclusions from it. This research will contribute in this sense.

2. RESEARCH OBJECTIVES

The overall purpose of this project is to analyze the effect of the different enforcement measures taken by regulators and the levels of organic pollution of industrial plants (as measured by tons of BOD_5 of their effluents) in Montevideo, Uruguay, during the period 1997-2007. More specifically, the research aims to answer questions (1) and (2) above. In order to answer these questions I will use advanced econometric techniques to estimate a model I describe below. The model basically tests a unique hypothesis: An increase in expected penalties, defined as the probability of being inspected multiplied

1 See Caffera (2007) for the references mentioned in this proposal.

by the amount of the corresponding fine, decreases the probability that an industrial plant would be out of compliance with effluent standards

3. RESEARCH METHODS

3.1. Data

The main equation to be estimated will have the following variables:

Dependent variables:

Biological Oxygen Demand (BOD_5) measure in effluents of plant i in month t and a zero/one dummy variable indicating plant's i compliance status in month t: These variables will be obtained from the reports that every four months industrial plants send to the municipal government of Montevideo.[2] In these reports, industrial plants inform monthly levels of the following variables: (1) production, (2) water consumed, (3) energy consumed, (4) number of employees, (5) days worked, (6) volume of effluents and (7) several parameters characterizing the plant's effluents. One of these parameters is mg/l of BOD_5. They report mg/l per month, on average, instead of loads, because emissions standards are set in terms of the level of concentration of the different parameters in their effluents, not in terms of loads. A plant is out of compliance if the mg/l of BOD_5 in its effluent exceeds the maximum set in the legislation. When this is the case, my dependent variable "Compliance Status" takes the value of one, and zero otherwise. From all the reported parameters I chose BOD_5 because industrial organic pollution is important in the city and because of data availability (every plant has to report BOD_5, regardless of its industrial branch).

Main explanatory variables:

Expected Penalty: The main explanatory variable will be the *expected penalty* that the industrial plant *i* faces in month *t* when it decides how much organic pollution to emit.[3] The expected penalty is the product of the *probability that the plant i faces of being inspected in month t* and the *amount of the corresponding fine*. According to the legislation, this fine depends both on the plant´s past violations record and the level of BOD_5 in effluents discovered when inspected. The probability of being inspected will be calculated fitting an auxiliary regression, as explained in more detail below.

Controls:

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[2] I already have the information for July 1997 – October 2001 for all variables mentioned in this proposal

[3] I refer to organic pollution as the level of BOD_5 in the plant's effluents.

Abatement Costs: According to the economic theory, the level of a pollutant emitted by an industrial plant that faces an emission standard (a maximum allowable level of pollution to emit) is the one that minimizes total expected costs. These are the sum of the expected penalty (in the case that the level of emissions chosen exceeds the standard), as explained above, and the abatement costs. The latter are the difference in (maximum) profits that the plant would have obtained in an unregulated setting and the (maximum) profits that the plant actually obtains when it emits less than the level of emissions in the unregulated setting (I am assuming that the emission standard set by the regulators is less than the level that the plant would have emitted in an unregulated setting). Following this theory, I will include the plant´s estimated profits as a control variable. This profit will be calculated using public information on product and input price indexes and the quantities of the goods produced and the inputs used by the plant *i* in month *t,* as reported by the plant. Profits calculated in this way are not an exact estimation of the plant´s profits because not all the inputs that the plants actually uses will be included in this calculation, but only the ones that they inform of to regulators in the reports. Specifically, the variable *profits* will be calculated using the following variables: (1) *Retail Price Index:* the level of this index for the product *k* produced by the plant *i* in month *t*, as published by the Central Bank of Uruguay, (2) *Industrial Water price index:* the level of this index in month *t*, as published by the Central Bank of Uruguay, (3) *Industrial Electricity Price index for the Industry:* the level of this index in month *t*, as published by the Central Bank of Uruguay, (4) *Industrial Salary Index:* the level of this index in month *t*, as published by the National Institute of Statistics, (5) *Production:* the level (in units of goods, Kilograms, cubic meters, etc.) of the good *k* produced by the plant *i* in month *t*, (6) *Water consumed*: cubic meters of tap water consumed by plant *i* in month *t*, (7) *Electricity consumed*: KW of electricity consumed by plant *i* in month *t*, (8) *Number of employees*: total number of persons that worked at the industrial plant *i* in month *t*, and (9) *Days worked*: total number of days that the industrial plant *i* operated in month *t*. Variables (5) to (9) above are as reported by the industrial plant to the municipal government.

Alternatively, instead of calculating a variable *profit* I will include, in another specification of the equation, the above mentioned variables directly as regressors, with the exception of *days worked* and *number of employees*, which I can merge in one variable called *labor.*

<u>Other controls:</u>

As described below, I will estimate a panel data with fixed effects by plant. This technique precludes me from using any time-invariant control for other plant's characteristic, such as the industry branch to which the plant belongs, or the level of environmental consciousness of the manager. All these characteristics are included in the fixed effect. One exception is the variable *Value of exports:* the value of the plant´s exports in US$ in month *t.* The idea is to control for the possibility that exporting plants would pollute less due to foreign markets requirements.

<u>Variables to be used in the auxiliary inspection equation:</u>

As explained in more detail below, I will run an auxiliary regression to calculate the variable *probability of being inspected* (to be used to calculate the expected penalty, main explanatory variable of the level of pollution). This is done by fitting this auxiliary regression once estimated. This auxiliary regression will have a zero/one dummy variable as the dependent variable (indicating whether the plant *i* was inspected in month *t* by the municipal or the national government). This dummy variable is calculated using the variable (1) *Inspections*: The number of inspections performed at the plant *i* in month *t* by the municipal and the national inspectors. Variables to be used in this auxiliary regression as covariates are the following: (2) *Compliance orders*: The number of compliance orders issued to the plant *i* in month *t* by the municipal and the national governments. Compliance orders are letters of warning sent to firms when a violation is discovered. The first letter indicates that the plant has a period of time to correct the situation, after which it could be fined. A second warning may be issued, (3) *Fines:* The number and amount of fines applied to the plant *i* in month *t*, (4) *Non-reports:* the number of times that plant *i* did not send the report in the last two opportunities, and (5) *Industrial Production Index:* the value of this index, as published by the Nation Statistics Institute. Variables (1) to (4) above are obtained from the municipal and national governments' records.

<u>Missing Values:</u> Several of all these variables present missing values. The variables reported by the industrial plants may be missing because the plant did not send the report, in which case I have missing values for all the variables in the report for the four months ("unit non-report"), or because a specific variable in the report in a given month is missing without apparent reason ("item non-report"). I will test for "ignorability" using Verbeek and Nijman's (1992) test. I will also test the effect of imputing values for the item non-report cases using an iterative Buck (1960) procedure, as suggested by Beale and Little (1975), for each plant.

The number of plants included in my sample is unknown yet. Again, I do not have with me yet the information regarding the period 2002 – 2007. I do have the information regarding the period 1997 – 2001. This information covers a total of seventy-four plants. But I do not know if everyone of these plants continue to operate or any other important plant started operation in any of these years. For both of these reasons (missing values and plants´ attrition) my panel is unbalanced.

3.2. Econometrics

Estimating the effect of enforcement actions on the level of the activity being controlled has the obvious problem of endogeneity. In the absence of a natural experiment, I will undertake several approaches to deal with this problem. In a first approach, I first run an auxiliary regression to calculate the variable *probability of being inspected* and then use this variable to construct the variable *expected penalty,* to use as main explanatory variable of pollution in my main regression. In order to construct the variable *probability of being inspected* I will run first the following auxiliary regression: The first specification of this equation is

$$I_{i,t} = g(H_{i,t-1}, IPI_t) \qquad (1)$$

$I_{i,t}$ is a zero/one dummy indicating if the plant *i* was inspected in month *t*. This is a function *g* of the variables $H_{i,t-1}$ and IPI_t. $H_{i,t-1}$ is a set of variables measuring the past enforcement record of plant *i* in month *t*. It includes the number of inspections, compliance orders and the total amount of fines received by the plant in the previous *12* months. It also includes the number of non-reports in the last two reporting periods. IPI_i is the industrial production index in month *t*. It is included given the possibility that Uruguayan enforces may decrease their inspections in hard economic times. Equation (1) will be estimated using panel data fixed effects techniques. Fixed effects are chosen over random effects because the number of plants in the sample is a large part of the population of industrial plants in Montevideo. Given this estimation approach, other time-invariant controls characterizing the plant cannot be included in the equation (1).

Specification 2 of equation (1) is the same except that the variables in $H_{i,t-1}$ are calculated going back 6 months instead of 12.

Specification (3) of equation (1) uses a composite measure of the plant's enforcement record. Instead of $H_{i,t-1}$ being a set of variables it is a unique variable calculated as the weighted sum of past inspections, compliance orders and fines.

Once estimated, equation (1) is fitted to obtain the variable *expected probability of being inspected.* At the same time, this variable is multiplied by the corresponding fine in case of being inspected, given the amount of BOD_5 reported by the plant for that month.

Specification one of the main equation to be estimated is the following

$$P_{i,t} = f(P_{i,t-1}, EP_{i,t}, B_{i,t}, X_{i,t}) \quad (2)$$

$P_{i,t}$ is a zero/one dummy variable indicating whether the plant i reported a level of BOD_5 in month *t* that is more ($P_{i,t} = 1$) or less ($P_{i,t} = 0$) than the emission standard. This variable indicates the compliance status of the plant. $P_{i,t-1}$ is the same variable indicating the compliance status of the plant in the previous month. Previous research suggested the inclusion of this variable as a regressor. The intuition besides this is that abating pollution (investing in a treatment plant, finding alternative inputs, etc.) takes time. $EP_{i,t}$ is the expected penalty faced by plant *i* in moth *t*, calculated as explained above. $B_{i,t}$ is th profits obtained by plant *i* in moth *t*, calculated as explained above. $X_{i,t}$ is the value in US dollars of the plant´s exports in month *t*, as explained above.

Specification 2 of equation (2) is the same, except that the dependent variables is $BOD_{5i,t}$.

Other forms to tackle with endogeneity will be pursued during the research. One possibility is to specify an explicit system of equations and estimate the reduced form. A priori, I do not think this could be a promising way to go because of how the enforcement process is actually done. The industrial plants report the level of BOD_5 in their effluents in month *t* at month *t+1, t+2, t+3* or *t+4*. This is because the reports are four-monthly. This means that the plant knows if it was inspected when it reports the level of BOD_5. Consequently I do not think is correct to say that the level of BOD_5 in plant's *i* effluents in month *t* and the decision to inspect plant *i* in month *t* by regulators are jointly determined. They are temporarily disjointed decisions. Nevertheless, I do think that the research could lead to the "discovery" of better instruments than the ones delivered by the above mentioned approach.

One possible problem with the interpretation of the results is that I found evidence of considerable under-reporting in my previous research by comparing the levels of BOD_5 reported by plants and the level found by regulators in inspections. If this is the case also in this new research, I will replicate the estimation using only the levels of BOD_5

the plants reported in the months they were inspected as a way to obtain better, albeit not perfect, estimates of the true effect of enforcement on pollution.

Finally, given that fines are not automatic (being discovered with or report a level of BOD_5 larger than the standard does not mean the plant is automatically fined) it may be worth calculating the *expected penalty* as the product of the *expected probability of being inspected* times the *expected probability of being fined*, instead of the corresponding fine. This would require estimating an auxiliary regression for fines also. Although promising, I am not able to give details in this proposal about the estimation method of this equation given that it would involve several of the same regressors that the inspection auxiliary regression involves.

4. EXPECTED RESULTS AND DISSEMINATION

I expect to: (a) obtain the answers of the research questions addressed, (b) test the hypothesis stated above, (c) improve the way past published papers dealt with the endogeneity problem, and (d) formulate relevant policy recommendations that may help regulators to improve the effectiveness of their enforcement activity regarding industrial effluents control. With respect to point (d), I hope to give regulators solid results (based on rigorous statistical analysis) of the relative effectiveness of the two enforcement strategies: compliance vs. deterrent. I am convinced this project will be of extreme help to them given their lack of resources that make them unable to conduct such a research. The conviction is based on impressions and comments received from both national and municipal authorities and inspectors, thanks to a fluid contact I maintained with them over the years since my last field work. As part of the retribution for having access to their database, I have committed to provide regulators with other specific analyses (like an analysis of the performance of a specific branch of the industry, or the analysis of the impact of the regulators activity on other aspects of the environmental performance of firms). I also plan to present the results of this research to regulators in seminars at the Municipal Government of Montevideo and the National Environmental agency, and academic conferences (ALEAR, EAERE, etc.). The research project will lead also to a non-technical publication for regulators in Spanish. Finally, I plan to publish a paper with the results of this research in the best possible field journal.

5. INSTITUTION AND PERSONNEL

I will be the only responsible researcher. See the attached CV describing my previous research experience. The research will be conducted in the facilities of the School of Business and Economics of the University of Montevideo, Uruguay. The other member of the research team will be a part-time research assistant (To be hired). This will be an advanced undergraduate student of economics or a graduate student, or another person with equivalent capacity to assist me in putting into an electronic database format the information regulators possess in their offices in paper format. This work includes reviewing every industry file and every dossier that the authorities open with every regulatory act.

6. TIMETABLE

Data gathering: 3 - 4 months. Literature review and estimation (data analysis): 3 months. Writing: 2 months. Dissemination: 1 month. (These estimations are in gross time terms. They account for the fact that this research will not be my only activity).

7. BUDGET

Direct research costs:

Research expenses:	
Remuneration to research assistant:	$1,500
New laptop computer [1]	$2,000
Local travel expenses [2]	$ 200
Dissemination:	
Seminars:	$1,000
Publishing and distribution of report in Spanish [3]	$1,000
Conferences' travel expenses:	$1,000
Overhead	$1,950
Remuneration:	
Honoraria for the principal researcher:	$6,350

Budget notes:

(1) Based on previous experience I estimate that both the desktop computer in my university office and my laptop computer are not adequate to run the planned regressions given the size of the database and RAM memory they have.

(2) Travel of principal researcher and research assistant to and from the regulators offices

(3) Does not include cost of translation/time cost of principal investigator