CIRANO

Centre interuniversitaire de recherche en analyse des organisations

Série Scientifique

Scientific Series

96s-33

Monitoring of Pollution Regulation: Do Local Conditions Matter?

Catherine Dion, Paul Lanoie, Benoit Laplante

Montréal
Novembre 1996

CIRANO

ISSN 1198-8177

Monitoring of Pollution Regulation: Do Local Conditions Matter?*

Catherine Dion[†], *Paul Lanoie*[‡], *Benoit Laplante*[§]

Résumé / Abstract

Les économistes ont beaucoup critiqué la réglementation qui impose des normes environnementales uniformes à des usines qui peuvent différer tant en terme de coûts marginaux de la diminution de la pollution qu'en terme des fonctions de dommage marginal. De tels critiques ignorent toutefois que l'implantation de normes peut varier de manière significative d'une usine à l'autre, ce qui se traduit par des normes qui, en fait, ne sont pas uniformes. Le but de cet article est d'analyser les déterminants des activités de contrôle du législateur, et les facteurs qui expliquent la décision d'inspecter ou non la performance environnementale d'une usine. Nous démontrons que les législateurs sont sensibles aux dommages environnementaux lorsqu'ils prennent la décision d'inspecter une usine spécifique et que de plus grands efforts d'inspection, ceteris paribus, sont consacrés aux usines qui sont susceptibles de créer les dommages les plus importants. D'un autre côté, nous démontrons également que les comportements du législateur sont aussi fonction de variables qui ne peuvent être reliées directement aux coûts de la réduction de la pollution et aux dommages environnementaux. En particulier, nous démontrons que les variables liées aux conditions locales du marché du travail ont un impact sur la stratégie de contrôle adoptée par le législateur. Ces résultats fournissent un support, à la fois à la théorie de l'intérêt public, et à la théorie économique de la réglementation.

Economists have greatly criticized regulations that impose uniform environmental standards on plants which may differ in terms both of their marginal abatement cost and marginal damage functions. Such a critic ignores however that the implementation of the standards may vary significantly across plants thus giving rise in fact to non-uniform standards. The purpose of this paper is to analyze the determinants of the regulator's monitoring activities, and the factors which explains the decision to inspect or not to inspect a plant's environmental performance. We show that regulators are sensitive to environmental damages in their decision to inspect specific plants and that greater inspection effort, ceteris paribus, is allocated towards those plants whose

---

* Correspondence Address: Benoit Laplante, The World Bank, Policy Research Department N10-015, 1818 H Street, N.W., Washington, D.C. 20433, United States.
Our thanks to Louis Trottier for his technical assistance, Pierre-Yves Cremieux and David Wheeler for helpful advice and comments. Usual disclaimers apply.

† Industry Canada

‡ École des Hautes Études Commerciales and CIRANO

§ The World Bank

emissions are likely to generate a higher level of damages. On the other hand, we also show that the behavior of the regulator is also a function of variables that may not be directly related to abatement cost and damages. In particular, we show that variables pertaining to local labor market conditions have an impact on the monitoring strategy adopted by the regulator. These results provide support to both the public interest and economic theory of regulation.

Mots Clés : Pollution, environnement, contrôle, réglementation, pâte et papier

Keywords : Pollution, Environment, Monitoring, Enforcement, Regulation, Pulp and Paper

JEL : L51, L73

1. Introduction

Economists have greatly criticized environmental regulations that impose on polluters *uniform* environmental standards since such standards ignore that plants face non-uniform marginal abatement cost, as well as non-uniform marginal damage functions. However, the presence of uniform standards does not necessarily imply uniform compliance with the standards. The nature of the monitoring and enforcement activities performed by the regulator ultimately determines the extent of pollution control undertaken by the plants and their level of compliance with the regulation.[1] If compliance with the terms of the regulation imposes any net cost on a plant, its behavior is likely to diverge from the desired one unless the cost of compliance is smaller than the expected cost of non-compliance.[2]

It has been increasingly recognized that resources devoted to the monitoring of the regulated community and the enforcement of environmental standards are insufficient, and that these activities are seriously lacking.[3] The regulator therefore has to allocate its limited resources to perform a small number of compliance activities. Silverman (1990) writes: "Because of limited resources and the resulting need to establish priorities, each EPA program at agency headquarters in Washington D.C. has developed compliance monitoring plans and enforcement response policies. These strategies *generally* direct the most intensive efforts to those segments of the regulated community most likely to be in non-compliance" (p. 95; italics ours). In the context, the use of

---

[1] Russell (1990) defines *monitoring* as "checking up on whether those covered by the law and regulations are doing (or not doing) what is required of (or forbidden to) them." (p. 243) *Enforcement* is defined as "taking actions that force violators to mend their ways and that provide visible examples to encourage others in the regulated population to maintain desired behavior to avoid a similar fate." (p. 243)

[2] Penalties for non-compliance may take various forms, including legal costs, fines, loss of reputation, etc. For more details, see Dewees (1990), Hamilton (1995), Lanoie and Laplante (1994), and Muoghalu et al. (1990).

[3] Russell (1990) writes: "What is missing is a commitment of resources to checking up on whether those covered by the law and regulations are doing (or not doing) what is required of (or forbidden) them" (p. 243). See also General Accounting Office (1993), and O'Connor (1994).

the word "generally" takes a special importance since it represents an implicit recognition that universal compliance may not be the objective of the regulator. Similarly in Canada, "upon evaluating the results of the National Inspection Plan, Environment Canada found that all regulations did not require the same level of compliance verification, and decided on a target-oriented approach" (Canada, 1992, p. 38).

Surprisingly, issues pertaining to the monitoring and enforcement of environmental standards has been the object of very few empirical analysis.[4] Magat and Viscusi (1990) have estimated the impact of inspections on the self-reported discharges of biological oxygen demand (BOD) of pulp and paper plants in the United States, and found that each inspection reduces permanently reported discharges by approximately 20%. More recently, Laplante and Rilstone (1996) have found that not only inspections but also the *threat* of an inspection has a strong negative impact on reported emissions. Both analyses also found that inspections induce more frequent reporting from the plants.[5]

Given that inspections may induce plants to improve their environmental performance, it is of interest to understand the process leading the regulator to undertake monitoring activities. The purpose of this paper is to analyze the determinants of the regulator's decision to monitor (or not to monitor) a plant's environmental performance. In particular, we have built a measure of environmental damages to test whether or not greater inspection effort, ceteris paribus, is allocated towards those plants whose emissions are likely

[4] We note,along with Cropper and Oates (1992), that most of the literature in environmental economics simply makes the (implicit or explicit) assumption that polluters comply with the regulation. Research effort on monitoring and enforcement issues has been for the most part theoretical (see for example, Beavis and Dobbs (1987), Linder and McBride (1984), and Russell et al. (1986)). Fisheries have attracted a certain number of empirical analysis (among others, see Furlong (1991), and Sutinen and Andersen (1985)).

[5] See also Fearnley et al. (1995).

to generate a higher level of damages. On the other hand, we also test whether or not the behavior of the regulator is a function of variables that may not be directly related to abatement cost and damages. We are particularly interested in testing whether or not variables pertaining to local labor market conditions (e.g. regional unemployment) has an impact on the monitoring strategy adopted by the regulator.

The paper most closely related to ours is Deily and Gray (1991).[6] Using solely the economic (or positive) theory of regulation as a reference model (Stigler (1971), Peltzman (1976)), they analyze whether or not local labor market conditions affect the enforcement of environmental standards.[7] In particular, they analyze whether or not EPA's *enforcement* actions are a function of the probability that a plant closes as a result of these actions instead of complying with the regulation. In a recent paper, Deily and Gray (1996) also use the economic theory of regulation to model the regulator's enforcement decision. As will be shown in Section III, we obtain results converse to those obtained by Deily and Gray. Moreover, unlike Deily and Gray (1991, 1996) who did not perform such a test, we show that greater inspection efforts are directed towards those plants most likely to cause higher levels of damages. This result lends support to the public interest (or normative) theory of regulation (Posner, 1974).

Given the limited number of empirical analysis in this area of research, we view our analysis as broadening further our understanding of the regulator's behavior with respect to the monitoring and enforcement of environmental standards. Our results indicate that unlike standards, the *implementation* of those standards is not uniform. To the extent that higher expected damages

---

6 Interestingly, Deily and Gray assert that their paper is "the first empirical study of the EPA's enforcement activity at the plant level" (p. 260).

7 This theory stipulates that there is a supply and demand of regulation, and that the government chooses the amount of regulation so as to maximize its political support.

lead to a greater probability of inspections, actual standards may be closer to optimality than would suggest the regulation. Moreover, given the specificities of our model, the current paper extends Deily and Gray's analysis (1991, 1996) to a test of the validity of the competing theories of regulation when applied to environmental issues.[8]

Our paper proceeds as follows. In the next section, we discuss in more details our model, estimation startegy, and the nature of our dataset. We present our results in Section III and conclude in Section IV.

2. Model, estimation and dataset

(i) *Model*

Our purpose is to analyse the factors that explain the regulator's decision to monitor a plant's environmental performance. Assume that a regulation is in place which restricts discharges of a given subset of industrial polluters (as most environmental standards are industry specific). Assume moreover that limited resources are devoted to monitoring compliance with the regulation. How is the regulator going to allocate its monitoring resources? As suggested by Silverman (1990), the regulator may wish to allocate its resources to maximise the rate of compliance with the regulation. If such is an objective, monitoring activities would obviously be a function of a plant's compliance history. In particular, a high frequency of non-compliance may trigger an inspection by the regulator. However, such a strategy would presume that compliance is equally desirable regardless of the impact of a plant's emissions on the environment. It would ignore that the impact of a plant's emissions is a function of the specificities of the environment in which they are discharged.

---

[8] To our knowledge, such a test has only been performed by Kaserman et al. (1993).

With respect to effluent discharges, for any given concentration of conventional pollutants (such as BOD and total suspended solids (TSS)), the environmental impact is a function of the flow of the effluents relative to the flow of the river in which the effluent is discharged: ceteris paribus, the greater the river flow, the smaller the environmental impact. Hence, given that the impact of a unit of pollution may vary considerably across locations, the regulator may wish to allocate its resources not so much as to increase compliance with the regulation but instead to minimise environmental damages. This behavior would support the public interest (or normative) theory of regulation which, applied to this particular instance, would explain environmental regulation as an instrument that corrects market failure and increases social welfare (Posner, 1974). Given this interpretation of the regulation, the regulator's monitoring strategy would, ceteris paribus, be explicitly affected by the fact that damages are heterogeneous across locations, and at least implicitly would allow higher discharges (through lower probabilities of inspections) in locations where damages are smaller.

However, other variables may also affect the regulator's behavior. If one espouses the economic (or positive) theory of regulation, the regulator would allocate monitoring resources so as to maximize net political suport. On this basis, Deily and Gray (1991, 1996) predict that local employment conditions would particularly influence enforcement actions. Enforcement actions in Deily and Gray include letters, phone calls, penalties, enforcement orders, inspections, etc. Monitoring activities (e.g. inspections) are not differentiated from enforcement activities (e.g. orders and fines). In particular, they predict that plants in high unemployment areas would be the target of a smaller number of enforcement actions than plants in lower unemployment areas. However, somewhat surprisingly they find that "plants in high-unemployment counties are facing more enforcement actions than fewer." (1991, p. 269).

Deily and Gray (1991, 1996) also predict that large plants (relative to the community labor force) would face a smaller number of enforcement actions since it may prove too costly for the regulator to disrupt a large proportion of the labor force (where the cost is measured in terms of political support). An alternative view however is that in order to maximize political support, the regulator may trade-off the support of those concerned with environmental quality with those whose income is an important function of the economic activity generated by the presence of a large (polluting) plant. Support from an environmentally aware community may be obtained by the undertaking of "visible" *monitoring* activities such as inspections, (irrespective of whether or not these inspections give rise to enforcement actions), while support from the group who benefits largely from the presence of the plant may be obtained by engaging into less *enforcement* actions. Hence, unlike Deily and Gray, we therefore predict that the "visibility" of the plants may affect the probability that it being monitored: the greater the visibility (measured as the importance of the plant in the local labor market), the larger the probability of inspections. Whether or not large plants in the local labor market face a smaller or a larger number of monitoring actions therefore remains an empirical issue.

Following the preceding discussion, we therefore seek to explain the regulator's monitoring activities by using a model specification which includes variables that could support both the normative and positive theory of regulation:

MONITORING = f (LOCAL EMPLOYMENT CONDITIONS, DAMAGE OF POLLUTION, COMPLIANCE, CONTROL VARIABLES)

(ii) *Estimation strategy and data*

For the purpose of our econometric analysis, we use plant-level monthly data from the pulp and paper industry in Quebec. The industry is a major contributor to Quebec's economic activity and is also its most important source of conventional pollutants, producing approximately 60% of the total BOD load produced by the manufacturing industry in Quebec. In Canada, jurisdiction over water pollution control is shared by the federal and provincial governments. The basis of the overlap relies on the Constitution Act of 1867. Insofar as water pollution is concerned, the federal government has played an important role through its "Fisheries Act" under which it has introduced the "Pulp and Paper Effluent Regulations" in 1971. Similarly, the government of Quebec, pursuant to its "Environmental Quality Act", has introduced the "Règlement sur les fabriques de pâtes at papiers" in 1981. As of May 1992, new federal and provincial regulations were introduced for the pulp and paper industry whereby new emission standards for TSS, BOD, toxicity, dioxins and furans have been defined. However, for the period covered by our sample of data (1985-1991 inclusively), only the Quebec regulation contained standards for BOD and TSS (and not for toxicity). These standards are *uniform* and apply equally to every plant in the industry. A plant's compliance with the regulation is assessed by comparing the allowable discharge with the total load reported by the plant.[9] Though 60 plants were in production over the period of analysis, a complete dataset was available for only 46 of those plants.[10] A total of 63 sampling inspections have been

[9] For more details, see Laplante and Rilstone (1996).

[10] Observations were missing from the monthly reports filed by the plants. In a number of cases, the neglect to report seemed to be unsystematic. These observations were treated as randomly missing and were replaced by forecasts from 12th-order univariate autoregressions. This left us with 46 of the 60 plants. As for the plants not included in our dataset, Laplante and Rilstone (1996) have shown that the failure to report does not appear to be the result of a strategic behavior from the plants.

performed by the regulator over the period of analysis.[11] However, due to the exclusion of 14 plants, we retain 56 of the 63 inspections.

Let us turn to the variables used to estimate the above equation. The definition, mean, and standard deviation of the variables are provided in Table 1. The dependent variable, MONITORING, is captured by a sampling inspection by the environmental authorities (INSP); it takes a value of 1 when there is an inspection and 0 otherwise.

[INSERT TABLE 1]

The LOCAL EMPLOYMENT CONDITIONS are captured by a vector of three variables similar to those used by Deily and Gray. First, EMPL is defined as the ratio of employment at the plant to employment in the local labor market.[12] Following our previous discussion, we expect a positive effect of this variable on the probability of an inspection: the larger the plant in the regional labor market, the more visible is the regulator's monitoring activities in the community. Political support may thus be more favorable from the constituents for whom environmental protection is an important determinant of their political support. Second, UNEMPL is the regional unemployment rate as defined and measured by Statistic Canada. Third, AGE represents the age of the plant. It reflects (admittedly crudely) the costs that a plant could face if non-compliance was detected, and therefore the potential impact on employment if a large plant is requested to reduce its emissions. We expect that each of these last two variables will have a negative impact on the probability of an inspection.

---

[11] A sampling inspection is an inspection where the regulator samples the plant's effluents and measures the content of the samples. Other types of monitoring activities are also performed (see Magat and Viscusi (1990, p.338) for more details). We have tried to document monitoring activities other than sampling inspections. However,in Quebec, during the period considered, monitoring activities were performed on a regional basis and it proved impossible to obtain comparable information across regions. It does remain the case that sampling inspections are the regulator's ultimate device to assess compliance with the standard and give credibility to the self-reporting procedure.

[12] The size of the local labor market is defined as the labor force within 100 km from the plant.

As a measure of the DAMAGE OF POLLUTION, we use 4 different variables: FLOW, ORGANO, POP, and ZONE. The variable FLOW represents the flow of the plant's effluent relative to the river flow. Conversations with experts in the Quebec Ministry of the Environment assured us that such a variable captures in a simple and reasonable way the potential of a plant's effluent to cause environmental damages. We expect this variable to have a positive impact on the probability of inspection: the larger the FLOW variable, the greater the potential for damages, and the higher the probability of an inspection. While this variable may capture the potential for conventional pollutants to cause damages, it ignores that the potential for organochlorides such as dioxins and furans to cause damages may not be affected in a same manner by the river flow. We have thus introduced the variable ORGANO which takes the value 1 if a plant's effluents contains such pollutants.

While emissions of pollutants likely reduce water ambient quality, the damages suffered from such reduction are a function of the various uses that can be made of the water. Ideally, we would have liked to estimate the economic value of the portion of the river affected by the plant's discharges and predict that the higher this value, the larger the probability of an inspection. Given the large number of rivers in which the plants in our sample are discharging, such an exercise would not have been feasible. Following discussion with the Ministry of the Environment, we have decided to consider as a proxy for damages, the population of the city in which the plant is located, only to the extent that the plant discharges its effluent upstream the location of the population (POPUL). If the plant's outlet(s) is located downstream the city, the variable takes the value 0.[13]

[13] Short of measuring the economic value of the river, we wished to estimate the number of people living within a given distance (e.g. 15 km) downstream the plant's discharge point(s). However, the required distance would itself have been a function of the river flow. A dispersion model for each river would then have been necessary to estimate the correct distance to include in the calculation for each plant. These models are lacking.

Finally, we have constructed a general index of environmental pressure for *each river* in which pulp and paper plants are discharging their effluents. We expect that the higher the environmental pressure, the more damaging could be a plant's effluents, and therefore the greater the probability of an inspection. We first calculated the following ratio: ((industrial wastewater discharges + domestic wastewater discharges) / flow of the river). We then have constructed an index ZONE which gives a value between 1 and 5 to the ratio calculated above with 1 representing an area of low pressure, and 5 an area of very high pressure.

We have also included a variable INCOME which measures the average household income within 100 km of the plant. We expect that the higher the level of income, the greater the demand for a cleaner environment, and the larger the probability of monitoring of the plant's environmental performance. It is interesting to note that this variable may give support to both theories of regulation. Following the public interest theory of regulation, ceteris paribus higher levels of income give rise to a higher valuation of the environmental damages and therefore to a smaller level of optimal pollution for any given levels of abatement cost. On the other hand, following the economic theory of regulation, communities with higher level of income may be more adept at exercising pressure on the regulator to reduce pollution emissions (higher demand for regulation).

COMPLIANCE is captured by the number of months that the plant was in compliance with BOD and TSS standards during the last twelve months. We therefore have two variables labeled COMPBOD and COMPTSS; they should have a negative influence on the probability of an inspection.

As discussed previously, if the LOCAL EMPLOYMENT CONDITIONS variables have a strong explanatory power, this would lend some support to the economic theory of regulation, while if the DAMAGE OF POLLUTION and the COMPLIANCE variables have more explanatory power, this would support the public interest theory of regulation.

Finally, we consider two sets of CONTROL VARIABLES. The first one is included to capture the differences in monitoring effort across administrative regions. For this purpose, we use either REGIONAL DUMMIES or, as in Deily and Gray, a variable labeled INSPREG which measures the total number of inspections within a region in a given year. The second set of control variables is included to capture omitted influences that may vary across time, but not across regions. For instance, greater public awareness of environmental issues through the period may have led to an increase in monitoring effort. These influences are captured either by YEARLY DUMMIES or a TIME TREND.

Given the dichotomous nature of our dependent variable,[14] we use the probit model for our estimations.[15] Different specifications are presented with various control variables. Furthermore, experimentations were conducted with different lags of the FLOW variable up to (t-6). The justification for this lies on the rationale that there may be a time lag between higher level of damages and the timing of an inspection. This is particularly true when using monthly data, with plants having to self-report their production and discharges data on a monthly basis.

3. Empirical results

We have first estimated different combinations of the control variables to account for regional effects (REGIONAL DUMMIES and INSPREG) and time

---

[14] There is no plant in our sample that had more than one inspection in a given month.

[15] We have tested a probit model with fixed effects (unconstrained model) by adding 45 dummies for plants, 11 dummies for months, and 6 dummies for years. None of these variables were statistically significant. We have also conducted a test of maximum likelihood. Results have shown that the unconstrained model was not preferable to the constrained version presented here.

(YEARLY DUMMIES and TIME TREND). With respect to regional effects, REGIONAL DUMMIES appeared to be never significant while INSPREG was always statistically significant. We thus present results using INSPREG. With respect to time, both YEARLY DUMMIES and TIME TREND were not significant. However, models with YEARLY DUMMIES were always performing better and we therefore keep this specification (results from various specifications are presented in Appendix 1).

Results are presented in Table 2. The first specification is a version analogous to Deily and Gray (1991) omitting the variables that capture the damage of pollution. the result of our basic model. The following specifications include various lags of the FLOW variable: $FLOW_t$ (2); $FLOW_{t-1}$ (3); $FLOW_{t-2}$ (4); $FLOW_{t-3}$ (5); $FLOW_{t-4}$ (6). Results show that the explanatory power of the model is relatively high with a percentage of correct predictions above 80%. For the purpose of our discussion, we will focus on the last four specifications which offer the largest percentage of correct predictions.[16]

[INSERT TABLE 2]

First note that the AGE variable is never significant and that its sign is unstable. To the extent that this variable may be use as a proxy for the cost of compliance, this result would indicate that the regulator does not consider compliance costs when allocating its monitoring resources across plants. It is interesting to note that Deily and Gray (1996) obtain a result of a similar nature. With respect to the variables pertaining to LOCAL EMPLOYMENT CONDITIONS, we observe that the coefficient of the EMPL variable is always positive and statistically significant thus indicating that the more important the plant is in the local labor market, or in other words the more "visible" is the plant, the greater the probability of

[16] For these specifications, we have also tested a logit version of the model. Results were of a similar nature and the percentage of correct predictions almost identical.

inspections: an increase of 1% in the variable EMPL increases the probability of inspection by 0.1135 %. As pointed out earlier, Deily and Gray (1991) obtained a contrary result. We explain this difference by noting that Deily and Gray included in their analysis (added together) both *monitoring* and *enforcement* activities while we here consider solely the impact of monitoring activities. If enforcement activities mainly explain the result obtained by Deily and Gray, the combination of our results with theirs would indicate that the regulator undertakes monitoring activities where its actions may be most visible (thus indicating an inclination to protect environmental quality), but remains reluctant to impose enforcement actions on those some plants which may be more adept at challenging the regulator or, as suggested by Deily and Gray, whose closure would be most disrupting to the local labor market.

The coefficient of our variable UNEMPL is as expected of a negative sign, and statistically significant for most specifications: the larger the level of unemployment in a region, the smaller the probability of inspections. Deily and Gray (1991) somewhat surprisingly obtained the converse result. They explain their result by suggesting that “to the extent that high-unemployment areas tend to be more populous or more polluted, the benefits from reducing emissions in such areas may be greater” (p. 270).

With respect to the variables capturing the impact of DAMAGE OF POLLUTION, the coefficient of the variable FLOW is positive as we predicted using the public interest theory of regulation, and is statistically significant when the variable is lagged 3 or 4 periods: an increase of 1% in the value of the ratio increase the probability of inspections by 0.00089. The maximization of social welfare would indeed indicate that plants whose discharges may create higher environmental damages face a higher probability of inspections. We cannot clearly explain why only the lagged value of the FLOW variable is significant. We note however that there is typically a period of a few months between the time when plants submit their discharge reports and the time when this information becomes available to local enforcers for actions.

Coefficients of the variables INCOME and ORGANO are never significant. The coefficient on the variable POPAVAL is unexpectedly negative and in most circumstances not significant. This indicates to us that a more precise proxy for the potential damages caused by a plant's effluent would need to be developed in order to test more precisely the impact of damages on monitoring activities. In this particular instance, we suggest that the use of the portion of each river along which pulp and paper plants are discharging should be precisely documented and analysed.

The variable capturing the number of months that the plant was in compliance with BOD environmental standards in the previous 12 months, COMPBOD, is sometimes significant with the expected negative sign: a greater frequency of non-compliance with BOD standards increases the probability of inspections. However, the variable COMPTSS has an unexpected positive sign but is never significant. This may suggest that the performance of a plant with respect to BOD is more likely to influence the regulator's behavior than its performance with respect to TSS (a similar result is found in Laplante and Rilstone (1996)). It also suggests that inspections are not purely random and that they tend to be concentrated where non-compliance (with BOD standards) is more important, as suggested by Silverman (1990).

This evidence suggests that both the public interest theory of regulation and the economic theory of regulation contribute to explain the decision of the regulator to monitor the environmental performance of regulated plants. In a sense, such results indicate pragmatically that both theories may be complementary, or that the "real" world is neither totally black or totally white. This contrasts with the results presented by Kaserman et al. (1993) whose empirical test strongly supports the economic theory of regulation.

4. Conclusion

Though environmental regulations impose uniform standards on plants that are facing heterogeneous local conditions (such as environmental damages and labor market conditions), results in this paper suggest that the monitoring of those standards is responsive to this heterogeneity. Ceteris paribus, plants whose emissions are most likely to impose high environmental damages are facing a higher probability of being inspected; similarly, the probability of an inspection appears to be an increasing function of the visibility of the plant and a decreasing function of the regional unemployment rate. We do believe that these results offer important insights into the regulator's behavior. First, it does suggest that regulators, facing limited resources, do not blindly enforce uniform standards as set and required by environmental regulation: ceteris paribus, monitoring effort is likely to be higher where environmental damages are higher. This result would suggest that it may be less costly to set (sub-optimal) uniform standards and let enforcers take care of the specificies of local conditions, instead of setting standards that reflect those specificities and letting no room to the enforcers to deviate from the standards. Secondly, we have shown that regulators do respond to both the visibility of the plant in the region as well as local labor market conditions. This result complements the result obtained by Deily and Gray (1991): regulators appear to *monitor* larger plants for visibility of their actions (and thus satisfy a subset of the electorate), but avoid enforcing the regulation for those larger plants (thus satisfying another subset of the electorate).

References

Beavis, B. and I. Dobbs (1987), "Firm Behavior under Regulatory Control of Stochastic Environmental Wastes by Probabilistic Constraints", *Journal of Environmental Economics and Management*, 15, 112-27.

Canada (1992), *The Green Plan: a Framework for Discussion on the Environment*, Ministry of the Environment, Ottawa, Ontario.

Cropper, M. and W.E. Oates (1992), "Environmental Economics: a Survey", *Journal of Economic Literature*, 30, 675-740.

Deily, M.E. and W.B. Gray (1991), "Enforcement of Pollution Regulations in a Declining Industry", *Journal of Environmental Economics and Management*, 21, 260-274.

--------- (1996), "Compliance and Enforcement: Air Pollution Regulation in the U.S. Steel Industry", *Journal of Environmental Economics and Management*, 31, 96-111.

Dewees, D.N. (1990), "The Effect of Environmental Regulation: Mercury and Sulphur Dioxide", In M.L. Friedland (eds), *Securing Compliance: Seven Case Studies*, Toronto: University of Toronto Press.

Fearnley, J., Lanoie, P. and M. Thomas (1995), "Firm responses to effluent regulations: Pulp and paper in Ontario, 1985-1989", Discussion paper no IEA 95- , École des Hautes Études Commerciales, Montréal.

Furlong, W.J., (1991), "The Deterrent Effect of Regulatory Enforcement in the Fishery", *Land Economics*, 67, 116-29.

General Accounting Office (1993), *Environmental Enforcement: EPA cannot Ensure the Accuracy of Self-Reported Compliance Monitoring Data*, Report RCED-93-21, Washington, D.C.

Hamilton, J.T. (1995), "Pollution as News: Media and Stock Market Reactions to the Toxics Release Inventory Data", *Journal of Environmental Economics and Management*, 28, 1, 98-113.

Kaserman, D.L., Mayo, J.W. and P.L. Pacey (1993), "The Political Economy of Deregulation: the Case of Intrastate Long Distance", *Journal of Regulatory Economics*, 5, 49-63.

Lanoie, P. and B. Laplante (1994), "The Market Response to Environmental Incidents in Canada: a Theoretical and Empirical Analysis", *Southern Economic Journal*, 60, 3, 657-672.

Laplante, B. and P. Rilstone (1996), "Environmental Inspections and Emissions of the Pulp and Paper Industry in Quebec", *Journal of Environmental Economics and Management*, 31, 19-36.

Linder, S.H. and M.E. McBride (1984), "Enforcement Costs and Regulatory Reform: the Agency and Firm Responses", *Journal of Environmental Economics and Management*, 11, 327-46.

Magat, W.A. and W.K. Viscusi (1990), "Effectiveness of the EPA'S Regulatory Enforcement: the Case of Industrial Effluent Standards", *Journal of Law and Economics*, 33, 331-60.

Muoghalu, Michael I., Robison, H. David and John L. Glascock (1990), "Hazardous Waste Lawsuits, Stockholder Returns, and Deterrence." *Southern Economic Journal*, 357-70.

O'Connor, D. (1994), *Managing the Environment with Rapid Industrialisation: Lessons from the East Asian Experience*, Organisation for Economic Co-Operation and Development, Paris.

Peltzman, S. (1976), "Toward a More General Theory of Regulation", *Journal of Law and Economics*, 19, 211-240.

Posner, R.A. (1974), "Theories of Economic Regulation", *Bell Journal of Economics and Management Science*, 4, 335-358.

Russell, C.S. (1990), "Monitoring and enforcement", in P.R. Portney (eds), *Public policies for environmental protection*, Resources for the Future, Washington, D.C.

Russell, C.S., Harrington, W. and W.J. Vaughan (1986), *Enforcing Pollution Control Laws*, Resources for the Future, Washington, D.C.

Silverman, S.L. (1990), "Federal Enforcement of Environmental Laws", *Massachusetts Law Review*, 75, 95-8.

Stigler, G. J. (1970), "Optimum Enforcement of Laws", *Journal of Political Economy*, 78, 526-36.

Stigler, G.J. (1971), “The Theory of Economic Regulation”, *Bell Journal of Economics and Management Science*, 2, 3-21.

Sutinen, J. and P. Andersen (1985), “The Economics of Fisheries Law Enforcement”, *Land Economics*, 61, 387-97.

APPENDIX 1
Further empirical results
(Pr > Chi-squared)

Variables	(1)	(2)	(3)	(4)
INTERCEPT	-2.3301 (0.0018)	-2.2477 (0.0094)	-2.3954 (0.0747)	-1.1634 (0.4382)
AGE	-0.00023 (0.9269)	-0.00048 (0.8528)	0.000533 (0.8476)	-0.00012 (0.9664)
UNEMPL	-0.0601 (0.0328)	-0.0676 (0.0230)	-0.0907 (0.0087)	-0.1359 (0.0008)
EMPL	0.0228 (0.0005)	0.0233 (0.0004)	0.0225 (0.0074)	0.0217 (0.0075)
COMPTSS	0.0179 (0.2721)	0.0245 (0.1975)	0.00199 (0.9008)	0.0213 (0.2830)
COMPBOD	-0.251 (0.1355)	-0.0228 (0.2067)	-0.0268 (0.0957)	-0.0242 (0.1768)
INSPREG	0.3316 (0.0001)	0.3653 (0.0001)	-	-
REG1	-	-	0.3594 (0.4221)	0.2936 (0.5146)
REG2	-	-	0.2248 (0.5267)	0.2176 (0.5500)
REG3	-	-	-0.3488 (0.3642)	-0.5580 (0.1645)
REG4	-	-	-0.0911 (0.7970)	-0.2263 (0.5333)
REG5	-	-	0.2306 (0.6039)	-0.0835 (0.8564)
REG6	-	-	-0.4644 (0.2759)	-0.5188 (0.2363)
REG7	-	-	-0.2704 (0.5751)	-0.1529 (0.7524)
REG8	-	-	-0.3096 (0.4437)	-0.2755 (0.5070)
INCOME	0.000015 (0.4493)	6.755E-6 (0.7584)	0.00005 (-0.0072)	0.000012 (0.7528)
TREND	-0.00555 (0.1580)	-	-0.0072 (0.2393)	-
YEAR85	-	0.2308 (0.4235)	-	0.6834 (0.0254)
YEAR86	-	-0.00625 (0.9807)	-	0.3248 (0.2093)
YEAR87	-	0.1869 (0.4819)	-	0.0290 (0.9132)
YEAR89	-	-0.2591 (0.4241)	-	-0.4796 (0.1331)
YEAR90	-	-0.3150 (0.2402)	-	0.3390 (0.1753)
YEAR91	-	-0.0737 (0.8068)	-	0.2113 (0.5292)
FLOW (t-4)	13.6256 (0.0008)	14.5539 (0.0004)	16.2489 (0.0001)	15.1007 (0.0002)

APPENDIX 1 (cont'd)

ORGANO	-0.1045 (0.5698)	-0.1075 (0.5653)	-0.1124 (0.5467)	-0.1598 (0.4097)
POPUL	-4.9E-6 (0.1422)	-4.65E-6 (0.1651)	-3.82E-6 (0.2486)	-3.7E-6 (0.2778)
ZONE	-0.0922 (0.2457)	-0.1088 (0.1789)	-0.1462 (0.0714)	-0.1339 (0.0961)
% correct predictions	83.3%	84%	72.3%	77.6%

TABLE 1
Variable definitions, means, and standard deviations

Variable	Definition	Mean	Standard deviation
INSP	Number of inspections per month at plant i.	0.02	0.12
AGE	Number of years of production by plant i.	63.74	32.49
UNEMPL	Unemployment rate in the economic region where the plant is located.	11.43	3.20
EMPL	Number of employees hired by the plant divided by total employment within a circumference of 100 km of the plant (in thousands) x 100.	5.72	8.54
COMPTSS	Number of months within the previous 12 months in which the plant complied with TSS standards.	6.79	5.00
COMPBOD	Number of months within the previous 12 months in which the plants complied with BOD standards.	6.74	5.05
INSPREG	Total number of inspections per year made in the administrative region where the plant is located, *excluding* inspections at the plant.	0.98	1.14

TABLE 1 (cont'd)

Variable	Definition	Mean	Standard deviation
REGIONAL DUMMIES	Dummy variable equals to 1 if located in the region, 0 otherwise (Region 9 is omitted from estimation):		
	Region 1	0.11	0.31
	Region 2	0.13	0.34
	Region 3	0.15	0.36
	Region 4	0.20	0.40
	Region 5	0.07	0.25
	Region 6	0.13	0.34
	Region 7	0.11	0.31
	Region 8	0.07	0.25
	Region 9	0.04	0.20
TREND	TREND = 1 for 01/1985, =2 for 02/1985, and so forth.	42.50	24.25
ANNUAL DUMMIES	1988 is ommited for estimation.	0.14	0.35
INCOME	Average annual household income within 100 km circumference of the plant.	34 185	4 715
ORGANO	Dummy variable to capture the presence of organochlorides in the effluent. Variable = 1 if contains; 0 otherwise.	0.02	0.35

TABLE 1 (cont'd)

POPUL	Population of the city if the plant's discharges are upstream the city. It takes a value of 0 if discharges are downstream the city.	14 551.76	21 798.72
FLOW	Ratio of flow of effluents over flow of river (m^3/sec).	0.009	0.032
ZONE	Polytomic variable taking a value between 1 and 5. 1 represents a zone where total environmental pressure on a river is low, and 5 where it is very high.	1.5681	1.053

TABLE 2
Empirical Results
(Pr > Chi-squared)

VARIABLE	(1)	(2)	(3)	(4)	(5)
INTERCEPT	-1.7070 (0.0173)	-1.5951 (0.0437)	-1.9481 (0.0119)	-1.9375 (0.0118)	-2.2590 (0.0036)
AGE	0.00186 (0.3473)	-0.0023 (0.2911)	-0.00107 (0.6209)	-0.00139 (0.5202)	0.00002 (0.9915)
UNEMPL	-0.0670 (0.0056)	-0.0603 (0.0363)	-0.0561 (0.0481)	-0.0597 (0.0346)	-0.0536 (0.0624)
EMPL	0.0225 (0.0001)	0.0242 (0.0001)	0.0239 (0.0001)	0.0219 (0.0005)	0.0230 (0.0004)
COMPTSS	0.0154 (0.3342)	0.0196 (0.2738)	0.0233 (0.1974)	0.0221 (0.2174)	0.0271 (0.1439)
COMPBOD	-0.0154 (0.3342)	-0.00691 (0.6727)	-0.0094 (0.5733)	-0.0102 (0.5337)	-0.0135 (0.4284)
INSPREG	0.3581 (0.0001)	0.3520 (0.0001)	0.3397 (0.0001)	0.3369 (0.0001)	0.3392 (0.0001)
INCOME	-9.4E-6 (0.5968)	-0.00001 (0.4511)	-9.17E-6 (0.6326)	-6.7E-6 (0.7262)	-3.9E-6 (0.8378)
YEAR85	0.1629 (0.5346)	0.1789 (0.5146)	0.2281 (0.4072)	0.2018 (0.4645)	0.3344 (0.2323)
YEAR86	-0.0768 (0.7481)	-0.1290 (0.6019)	-0.1062 (0.6653)	-0.0875 (0.7201)	-0.1042 (0.6732)
YEAR87	0.0737 (0.7705)	0.0943 (0.7144)	0.0769 (0.7642)	0.0808 (0.7517)	0.0694 (0.7873)
YEAR89	-0.1254 (0.6642)	-0.2421 (0.4364)	-0.2721 (0.3782)	-0.2765 (0.3684)	-0.3208 (0.3098)
YEAR90	-0.2076 (0.3848)	-0.1985 (0.4159)	-0.2114 (0.3864)	-0.2134 (0.3817)	-0.2645 (0.2857)
YEAR91	0.0750 (0.7740)	0.0553 (0.8425)	0.00926 (0.9732)	0.00369 (0.9893)	-0.0202 (0.9414)
FLOW	-	-9.1933 (0.1770)	2.0440 (0.6173)	1.7193 (0.6823)	8.8449 (0.0081)
ORGANO	-	-	-	-	-
POPUL	-	-	-	-	-
ZONE	-	-	-	-	-
% correct predictions	81.2%	80.6%	80.5%	80.0%	83.1%

TABLE 2 (cont'd)

VARIABLE	(6)	(7)	(8)	(9)
INTERCEPT	-2.4927 (0.0020)	-2.4975 (0.0022)	-2.8672 (0.0007)	-2.2477 (0.0094)
AGE	0.00025 (0.9118)	0.00063 (0.7940)	0.00062 (0.7969)	-0.00048 (0.8528)
UNEMPL	-0.0456 (0.1214)	-0.0480 (0.1085)	-0.0448 (0.1350)	-0.0676 (0.0230)
EMPL	0.0218 (0.0011)	0.0213 (0.0019)	0.0224 (0.0012)	0.0233 (0.0004)
COMPTSS	0.0214 (0.2509)	0.0234 (0.2167)	0.0217 (0.2479)	0.0245 (0.1975)
COMPBOD	-0.0198 (0.0255)	-0.0217 (0.2257)	-0.0246 (0.1804)	-0.0228 (0.2067)
INSPREG	0.3520 (0.0001)	0.3649 (0.0001)	0.3760 (0.0001)	0.3653 (0.0001)
INCOME	6.42E-7 (0.9742)	-8.16E-9 (0.9997)	0.000013 (0.5507)	6.75E-6 (0.7584)
YEAR85	0.3130 (0.2734)	0.2941 (0.3107)	0.3005 (0.2998)	0.2308 (0.4235)
YEAR86	-0.0500 (0.8431)	-0.0574 (0.8216)	-0.00971 (0.9698)	-00.625 (0.9807)
YEAR87	0.1376 (0.6010)	0.1465 (0.5792)	0.1561 (0.5592)	0.1869 (0.4817)
YEAR89	-0.2521 (0.4316)	-0.2529 (0.4343)	-0.2523 (0.4362)	-0.2591 (0.4241)
YEAR90	-0.2547 (0.3240)	-0.2960 (0.2620)	-0.3261 (0.2209)	-0.3150 (0.2402)
YEAR91	-0.0711 (0.8076)	-0.0729 (0.8053)	-0.1483 (0.6252)	-0.0737 (0.8068)
FLOW	9.2607 (0.0050)	11.1915 (0.0005)	11.2020 (0.0005)	14.5539 (0.0004)
ORGANO	-	-0.0239 (0.8925)	-0.1123 (0.5496)	-0.1075 (0.5653)
POPUL	-	-	-6.7E-6 (0.0716)	-4.6E-6 (0.1651)
ZONE	-	-	-	-0.1088 (0.1789)
% correct predictions	83.6%	83.9%	85.2%	84.0%

Liste des publications au CIRANO ·

Cahiers CIRANO / *CIRANO Papers* (ISSN 1198-8169)

96c-1 Peut-on créer des emplois en réglementant le temps de travail ? / par Robert Lacroix

95c-2 Anomalies de marché et sélection des titres au Canada / par Richard Guay, Jean-François L'Her et Jean-Marc Suret

95c-1 La réglementation incitative / par Marcel Boyer

94c-3 L'importance relative des gouvernements : causes, conséquences et organisations alternative / par Claude Montmarquette

94c-2 Commercial Bankruptcy and Financial Reorganization in Canada / par Jocelyn Martel

94c-1 Faire ou faire faire : La perspective de l'économie des organisations / par Michel Patry

Série Scientifique / *Scientific Series* (ISSN 1198-8177)

96s-32 Technological Learning and Organizational Context: Fit and Performance in SMEs / Élisabeth Lefebvre, Louis A. Lefebvre et Lise Préfontaine

96s-31 Piece Rates, Fixed Wages, and Incentive Effects: Statistical Evidence from Payroll Records / Harry J. Paarsch et Bruce Shearer

96s-30 R&D Spillover and Location Choice under Cournot Rivalry / Ngo Van Long et Antoine Soubeyran

96s-29 Efficient Income Redistribution in a Growing Economy / Gerhard Sorger

96s-28 Wage Flexibility and Contract Structure in Germany / Lars Vilhuber

96s-27 Setting Standards for Credible Compliance and Law Enforcement / Marcel Boyer, Tracy R. Lewis et Wei Len Liu

96s-26 American Options with Stochastic Dividends and Volatility: A Nonparametric Investigation / Mark Broadie, Jérôme Detemple, Eric Ghysels et Olivier Torrès

96s-25 How Did Ontario Pulp and Paper Producers Respond to Effluent Regulations, 1985-89? / Paul Lanoie, Mark Thomas et Joan Fearnley

96s-24 Nonparametric Estimation of American Options Exercise Boundaries and Call Prices / Mark Broadie, Jérôme Detemple, Eric Ghysels et Olivier Torrès

96s-23 Asymmetry in Cournot Duopoly / Lars-Hendrik Röller et Bernard Sinclair-Desgagné

96s-22 Should We Abolish Chapter 11? Evidence from Canada / Timothy C.G. Fisher et Jocelyn Martel

96s-21 Environmental Auditing in Management Systems and Public Policy / Bernard Sinclair-Desgagné et H. Landis Gabel

96s-20 Arbitrage-Based Pricing When Volatility Is Stochastic / Peter Bossaert, Eric Ghysels et Christian Gouriéroux

96s-19 Kernel Autocorrelogram for Time Deformed Processes / Eric Ghysels, Christian Gouriéroux et Joanna Jasiak

96s-18 A Semi-Parametric Factor Model for Interest Rates / Eric Ghysels et Serena Ng

96s-17 Recent Advances in Numerical Methods for Pricing Derivative Securities / Mark Broadie et Jérôme Detemple

96s-16 American Options on Dividend-Paying Assets / Mark Broadie et Jérôme Detemple

---

· Vous pouvez consulter la liste complète des publications du CIRANO et les publications elles-mêmes sur notre site World Wide Web à l'adresse suivante :
http://www.cirano.umontreal.ca/publication/page1.html