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How Did Ontario Pulp and Paper Producers Respond to Effluent Regulations, 1985-89?

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How Did Ontario Pulp and Paper Producers Respond to Effluent Regulations, 1985-89?[*]

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Résumé / Abstract

Cet article explore les effets de la réglementation des émissions de polluants sur les firmes de l'industrie ontarienne des pâtes et papier. Le modèle utilise des variables instrumentales pour faire la distinction entre les effets liés à la « capture » de l'agence de réglementation et des effets vraiment propres à l'action du régulateur. Le modèle cherche également à identifier les moyens utilisés par les entreprises pour faire face à la réglementation : des données sont disponibles pour les dépenses en équipement anti-pollution des entreprises et sur la quantité d'eau consommée. Les résultats tendent à démontrer que le contrôle des émissions polluantes se ferait de façon plus efficace par l'imposition d'une limite sur les rejets de matières en suspension (MES) que par une limite sur la demande biochimique en oxygène. Les effets constatés sur la firme d'une limite sur les MES, proviendraient en partie d'une modification dans la production, qui aurait pour effet de diminuer les émissions. Par contre, les investissements en équipement anti-pollution, consentis pour atteindre les objectifs de réduction de DBO, n'ont eu aucun effet sur les émissions. L'impact des poursuites légales, des amendes et des enquêtes est impossible à détecter. Parmi les causes possibles de ces résultats, notons que les sanctions imposées par l'Ontario aux entreprises lors d'une infraction sur l'émission de polluant, durant la période d'étude, étaient trop faibles pour influencer de façon mesurable le comportement des entreprises. Une autre cause pourrait être le fait que les limites d'émissions sont assez élevées pour ne pas être contraignantes pour la plupart des firmes de l'échantillon.

This paper explores the effects of effluent regulatory activity on firm behavior in the pulp and paper industry in Ontario. The model uses instrumental variables to attempt to distinguish between that correlation between emission limits and emissions coming from regulatory capture and that coming from true influence on the part of the regulator. The model also attempts to identify the response channels on the part of the firms: data are available on reported investments in abatement capital and on firms' water consumption, correlated with output. Estimation results suggest that total suspended solids (TSS) limits were more effective than biological oxygen demand (BOD) limits in controlling emissions. Firm responses to TSS limits were in part through modulating output and these responses lowered

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emissions. In contrast, firms reported investing in abatement technology in response to reductions in BOD limits, but these reported investments had no discernible impact on emissions. Firm responses to court summons, fines, and inquiries were impossible to detect. Possible causes of these results are that penalties for effluent discharge infractions in Ontario during the period studied were too light to influence firm behavior measurably, and that emission limits are set high enough not to be binding for most firms in the sample.

1. Introduction

In June 1986 the Ontario provincial government in Canada announced the imminent introduction of the Municipal Industrial Strategy for Abatement (MISA, finally introduced in 1990), a piece of legislation which collected under one heading, and strengthened, a variety of previous abatement initiatives. Emissions regulation in Ontario has to date been of the command-and-control variety, and MISA remains within this category. Firms are required to invest in a given 'best available technology', for which they receive a 'certificate of approval', and are then subject to 'control orders', which specify performance requirements, in terms of pollution 'loading', for the given technology. One objective of MISA was to standardise these requirements across firms and locations.

For the pulp-and-paper industry, the aim is to control two main measures of water pollution. The first, biological oxygen demand (BOD)[u], is not a direct measure of any particular pollutant, but measures the effects on the environment of a number of water pollutants. The second, total suspended solids (TSS), is a direct measure of the presence of solid waste emissions in the water supply. The two measures are often correlated, but constitute separate policy goals and require, to some extent, different abatement technologies (see, for example, Environment Canada, 1983, Chapter 13).

From the perspective of economic theory, command-and-control systems like MISA and its immediate predecessors in Ontario are a second best solution to the problem of the spillover effects linked to pollution by firms. Even if the socially optimal level of pollution is achieved, it will not, in general, be achieved at minimum cost by such systems of legislation. The informational requirement that such a system imposes on the regulator is in general greater than that imposed by market-driven legislative systems such as tradable permits or emissions taxes. Moreover, Milliman and Prince (1989, 1992; see also Marin, 1991) discuss the effects of different regulatory regimes on technical innovation in pollution abatement, and conclude that command-and-control mechanisms of the type discussed in this paper will in general stifle such innovation.

Given that current Canadian legislation is of the command-and-control variety, however, this paper analyses a complementary question to that referred to in the preceding paragraph. Are the systems currently in place achieving their own self-stated aims? For the pulp-and-paper industry during the period of 1985-1989 in Ontario, we examine the effects on firm behaviour of four measures of regulatory activity. These are (1) the inspection of factories, (2) the initiation of proceedings against firms, (3) the imposition of penalties on firms found to have transgressed

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[u] 5-day BOD, often also abbreviated to BOD5.

1

pollution limits, and (4) the creation of new emission limits.

Lanoie and Laplante (1994) have examined stock-market responses to the announcement of environment-related lawsuits against firms in Canada, the announcement of fines imposed, and the announcement of investment in new anti-emissions equipment. They find that the market responds only to the latter two (a fall of 2 percent in stock-market value typically follows a fine, a fall of 1.2 percent typically follows the announcement of anti-emissions investment), which represent realised, rather than potential, costs of regulation to firms. Their results are in contrast with those of Muoghalu, Robison, and Glascock (1990), in the United States, who find that the market tends to discount future expected losses on the day of an announcement of a lawsuit pertaining to environmental offences. Lanoie and Laplante conclude that the probability of conviction and the expected level of fines are probably not sufficiently high in Canada to create a market response, since it is only realised losses which are treated as 'news' by the market. Other possibilities are that the market does not believe that fines will be imposed or that firms will in fact make abatement investments. If stock-market valuation is the objective of a firm, then, we may conclude that the stringency of the regulatory environment may be insufficient in Canada to create the incentive to reduce emissions significantly, whereas one would draw the opposite conclusion in the U.S. This provides the motivation for the empirical analysis of this paper.

Related Work

Magat and Viscusi (1990) estimate two models of the observation of federal BOD-limits by 77 pulp-and-paper factories in the United States for the period 1982-85. The first model measures firm response as the level of BOD, and uses ordinary-least-squares regression to relate this to federal regulatory effort. In the second model, firm observation or non-observation of Environmental Protection Agency (EPA) BOD-limits is represented, by a logit model, as a response to regulatory effort. In both models, regulatory effort is measured using dummy variables indicating inspections in each of the six periods prior to the observation date, and the data is quarterly. Magat and Viscusi find a high degree of persistence in emissions levels, *ceteris paribus*, and that these emissions are responsive to inspection effort. These two effects combined imply that increased inspection could have a lasting impact on emissions levels. They then go on to conduct a benefit-cost analysis of the EPA regulations.

Recently, Laplante and Rilstone (1996) have gained positive results from a similar model to Magat and Viscusi's applied to monthly data in Québec, Canada. Their innovation is to model the decision to inspect as a response on the part of the regulator, and to use the probability-measure of inspection in a period so generated as the independent variable to which the firm responds. This approach reveals significant firm responses to the credible (in the sense that it is based on experience)

2

threat of inspections. Using Ontario data, however, we failed to reproduce this result, and indeed there is no sign of firm responses to inspections in this data. This may be because the threat of high enough fines to have a significant incentive effect is not credible, or it may be due to differences in the definition of an 'inspection' between the two provinces.[UU]

The above studies, while important, focus on only one aspect of the regulatory framework, namely the frequency of inspections, and its effect on emissions. This framework comprises many elements in addition to inspections, however: the severity of limits, the likelihood of summons and fines, the amounts levied, as well as the complex process of lobbying and consultation that precedes the introduction of any legislation. A broader quantitative analysis should encompass as many of these elements as the data permit. For example, limits may become more stringent without any response on the part of firms if fines are negligible, or if inspections are too rare. Another possibility that needs to be considered is that regulatory bodies may be 'captured': that is, limits set in response to firms' desired levels of output rather than independent benefit-cost analysis. This paper, to our knowledge, represents the first attempt to model this process, and to investigate the effectiveness of the heart of the regulation, the emissions limits themselves.

The rest of the paper is organized as follows. Section 2 presents the data. Section 3 discusses the empirical specifications and results, starting with a simple formulation where emission limits are postulated to influence emissions directly, and going to a more realistic formulation where limits can influence emissions through two important channels: changes in investment and changes in output. As will become evident, the results from these two different approaches are fairly different. Section 4 concludes.

2. Data

Data are available in Ontario, for 26 pulp and paper mills during the period 1985 to 1989, which allow us to explore the relationships between limits and other regulatory variables, and firm behavior. The data come mostly from the Ontario Environment Ministry and the Canadian Pulp and Paper Report, and a summary of variables is presented in Table 1. (All Tables and Figures will be found at the end of the article.) See Fearnley (1993) for further details on the compilation of the dataset.

Effluent emissions are available by firm, by month, for the two forms of pollution for which the legislation applies, BOD and TSS. Emissions are those reported by

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[UU] In the case of Ontario, the 'inspections' are inquiries, only launched if contraventions are suspected, whereas in the Québec data these were sampling inspections.

the firm to the Ontario Ministry of the Environment, and so we cannot discount the possibility of false reporting. Conversations with people in the industry suggest that this is not a serious problem, but strictly speaking we must admit that there is nothing that we can do about this shortcoming in our data, also present in related studies.

Regulatory variables are the following. First, the legal limits or guidelines in place are available (*bodlim* and *tsslim*). Next there are cumulative variables taking positive values when a firm faced a summons, was fined, or was under inquiry (*summons*, *fine*, *inquiry*—these variables take the value 1 at the first instance, 2 at the second, and so on). They are cumulative in order for the regression results to be sensitive to lasting effects due to these factors, rather than one-shot reductions in output or emissions following, say, an inquiry.

Firm response variables are available for both investment and production. Yearly investment in abatement technology is recorded in the Canadian Pulp and Paper Report for 15 of the firms in the sample. Accordingly, we restrict our observations to these 15 firms. These reported investment figures may be subject to two biases. First, reporting is on a voluntary basis, so there may be incentives for firms not to report investments for competitive reasons, leading to an underestimation of investment. Second, in order to illustrate a willingness to environmental lobby groups or to government, there may be incentives for firms to report investment which was not undertaken for environmental reasons as such (but which may nevertheless have an incidental effect on emissions—at issue is not firms' honesty but any bias in our data). This effect would of course offset the first, and it is impossible to say which bias, if either, might dominate. Nevertheless, we do expect these figures to be reasonably highly correlated with the true investment figures for the 15 firms. For production levels we use the firms reported throughput of water (*output*), again available from industry statistics. This is not an exact measure of production—these figures for individual firms are confidential—but we expect that it is sufficiently highly correlated to act as a close proxy.

3. Empirical Results

Exploring the Data with a Simple Specification

Table 2 gives the results from a naive pooled regression of emissions on the regulatory variables.[uuu] *Fine* and *summons* are lagged by one month to allow for time to respond on the part of the firms. Columns I-IV relate to BOD, V-VIII to TSS. To check for robustness we ran the regressions with two sets of dummies,

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[uuu] See Kmenta (1986, PP. 618-22) for details of pooled regression techniques.

first with identifiers for the river basin and the season, second with identifiers for the region and the month, both times also including subindustry identifiers. These dummy variables are jointly significant at conventional levels, as indicated by the F-statistics reported at the bottom of this and later Tables in the paper.

Column I shows a strong relation between the emissions limit and actual emissions, though the coefficient is less than unity. This coefficient falls by a further 50 percent when past emissions are included on the right hand side, along with the plant's capacity (which is highly significant) and its utilization rate (column II). Similar results hold for TSS in columns V and VI, but the relationship between emissions and limits is stronger, though still significantly less than unity.

These regressions are reported simply as a means of exploring the data and reporting partial correlations. There is clearly no sense in which the results in Table 2 should be considered as any evidence of causality from limits to emissions. If firms manage to influence the regulator's choice of limit, for example, then rising emissions may well lead to rising limits. This is one possible explanation of results such as those reported in Table 2. Notice also (column II, for example) that for BOD at least, summons seem to precede small rises in emissions rather than falls.[UUUU] The data cannot distinguish between different possible explanations for this. One is that firms may 'relax' once a court verdict is announced, not expecting further regulatory activity for a while. Another is that court verdicts may occur at times of high emissions lasting more than just one or two months.

Introducing Firm Behavior

One way to approach the problem of inferring causality from correlation is to examine firms' behavior as measured by observable quantities other than the emissions themselves. Firms may invest in abatement capital, for example, or reduce output, in response to changes in the stringency of the regulatory environment they face. Since data exist on firms' reported abatement investments, as well as on the volume of water the firms use (highly correlated with output in the pulp and paper industry), we may wish to include these variables in an analysis of the effects of the regulations.

Tables 3A (BOD) and 3B (TSS) add these elements to the 'naive' analysis reported in Table 2. In each Table columns I and II report coefficients from a regression of firms' reported abatement investment on emissions limits, court summons, fines, inquiries, investments a year ago, and the capacity utilization to control for the

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[UUUU] Where variable names have a time subscript (eg, $fine_{i,-1}$), this indicates a lag of that variable.

business cycle.[UUUUU] The 12-month lagged dependent variable is included to control for persistence—some firms may systematically invest more than others, or past investment may reduce the need for investment this period. Since one might reasonably expect investment to respond to changes in the regulatory environment, both the emissions limit and its year lag are included. A specification in which only changes in limits mattered would constrain these two coefficients to sum to zero, a hypothesis which cannot be rejected for the specifications reported in columns I and II (the difference between the columns again being in the sets of dummy variables included). For BOD there does seem to be a significant correlation between changes in the emissions limit and reported investment in abatement capital.

Columns III and IV relate output (measured by water flow through the plant for the month) to the regulatory variables. There is no evidence of any significant relationship between output and emissions limits, once the plant's capacity is controlled for. For both BOD and TSS, regulatory inquiries are seen to correspond with periods of relatively higher output, which is perhaps not surprising.

Do firms' changes in behavior, if any, as measured by investment and output, actually affect emissions? Columns V and VI in Tables 3A and 3B report coefficients from regressions of emissions on the regulatory variables, but also including the predicted values ($\widehat{INVEST}_{t-12}$, $\widehat{\textbf{OUTPUT}}$) from the investment (lagged by a year to allow for time to build) and output equations (columns I-IV in the same Tables). These predicted values therefore represent the components of investment and output that were responses to regulatory activity, be it changes in limits, summons, fines, inquiries, or combinations of these. [UUUUUU]

Tables 3A and 3B show that the coefficients on the emissions limits remain little different from their counterparts in Table 2: little of the correlation between limits and emissions is captured by our measures of firms' investment and output responses. Nor is there any evidence that the investment responses had any effect on actual emissions. Finally, only for TSS do the firms' output responses seem to have any impact on emissions (Table 3B).

The Full Model

The regressions reported in Tables 2 and 3 suggest that it is difficult to detect firms' responses to environmental regulations through investment or modulation of output.

[UUUUU] *Fine*, *summons*, and *inquiry* are lagged by a year in the investment equation to allow time for firms to react and for the investments to be announced in the following year's publication.

[UUUUUU] The lagged dependent variables proved to be necessary to gain consistent estimates due to serial correlation among the residuals when these lags were not included.

Columns V and VI of Tables 3A and 3B do describe, however, the same significant relationship between the limits themselves and emissions, these coefficients being as high as 0.4 for BOD and 0.6 for TSS. These correlations still pose a problem of inference. Do they represent firms controlling their emissions in response to exogenous changes in regulation imposed by government agencies? Or, less optimistically, do they represent regulatory capture: the tailoring of the limits to correspond to plants' needs, after taking into account their capital investments and planning decisions?

The possibility of capture of a regulatory body by the agents that it is supposed to regulate is well known, but this possibility is not reflected in any of the analysis so far. Such capture is of course just an extreme example of the generic tendency for regulation not to be entirely exogenous to the phenomenon being regulated. Environmental limits are usually set following procedures of consultation with those being regulated, and therefore might be believed to respond not only to exogenous environmental factors (the costs and benefits of the pollution), but to existing constraints, lobbying, and so on. Figure 1, at the end of the text, which shows emissions and limits for a subset of the plants in the sample, is also suggestive of limits responding to past emissions or firms' requirements: changes in limits often seem to follow changes in emissions rather than the opposite (see in particular Figure 1b). In equation form, we are particularly interested in the limits placed on emissions, and these may be said to be endogenous to the extent, if at all, that they are affected by firm actions (e.g., production) and characteristics (e.g., technology, capacity) and past pollution levels. [uuuuuuu]

An econometrician's answer to the identification problem described here might be to look for instruments to generate an exogenous component of regulation. One could then examine whether firms' behavior appeared responsive to this exogenous component.

What might such instruments look like? On one hand, we might consider as candidates attributes of the plants which affected the seriousness of the environmental threat posed by emissions into their water sources. These variables could reasonably be expected to affect government agencies' regulatory decisions,

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[uuuuuuu] The importance of being able to distinguish between endogenous and exogenous legislation is paramount, as can be seen from two stylized examples. In the first, government legislation is set completely exogenously, that is, in response to whatever criteria the government deems appropriate without consulting the firms, and penalties are sufficiently credible that a representative firm pollutes at exactly the prescribed limit. The second case is the opposite of the first—the legislation process is completely captured by firms, who cause limits to be set exactly in accordance with their production targets, and so of course subsequently observe these limits, and cause penalties to be light. An empirical observer would see a perfect correspondence between limits and emissions in both cases, and might erroneously conclude in the second that lowering the limits would cause a corresponding fall in emissions. But it is firms' likely reaction to an *exogenous* change in legislation which we would like to estimate in the context of evaluating the effectiveness of the legislation in controlling firm behaviour.

but should not affect firms' decisions regarding output or investment other than as responses to these decisions. Locational variables might constitute an example of such variables. Time dummies or trend terms might also be acceptable if we thought that the regulator's view of the seriousness of emissions were evolving over time. On the other hand, we might consider attributes of the plants that were controlled by firms' decisions, but only over the medium to long term. Plant capacity could be considered such an attribute. These variables may also affect the regulator's decisions over limits, but would not be alterable by the firms quickly enough to be viewed as responses to regulation.[uuuuuuuu]

The third set of regressions performed for this paper are an attempt to implement the estimation strategy described in the previous paragraphs. First, the emissions limits themselves are regressed using ordinary least squares on a trend term interacted with dummy variables for the plants' river basin location, and the trend term interacted with the plants' capacities. These variables constitute the richest set of instruments we could generate from the data using the logic of the previous paragraph to define exogeneity. This first stage regression is reported in Table 4 for both BOD and TSS limits.

The second stage of the analysis is to relate firms' decisions concerning investment and output to the predicted values from the first stage regressions, which we interpret as 'exogenous regulatory activity'. These results are shown in columns I-IV of Tables 5A and 5B for BOD and TSS respectively. Columns I and II give our two specifications for the investment equation, relating firms reported abatement investments to exogenous limits, lagged limits, year lagged summons, fines, and enquiries, and capacity utilization (again a proxy for the business cycle).

For BOD, in the second specification there is a significant relationship between exogenous changes in the limit and reported investment and we interpret this as an interesting indication. Moreover, as in the simple specification of Table 3A, the hypothesis that the coefficients on the current and lagged limits sum to zero cannot be rejected at conventional significance levels. The magnitude of these coefficients is also similar to that in Table 3A. It seems likely that firms, then, are responding to changes in BOD limits by announcing abatement investments. There is, however, no evidence that the same is true for TSS limits (Table 5B, columns I and II).

Columns III and IV in Tables 5A and 5B give the results of the two specifications of the output equation. These equations are the counterparts of columns III and IV of Tables 3A and 3B, with the emissions limits replaced with instrumented values.

[uuuuuuuu]Actually, a Hausman test for the endogeneity of the limits (performed from specifications III and VII in Table 2, using basins as an instrument) generated t-statistics of 6.5 and 5.0 for BOD and TSS respectively, so we can comfortably reject exogeneity of emission limits in the strict statistical sense implied by the use of this test.

For BOD the coefficients in both specifications are significant only at the ten percent level. For TSS they are significant at all conventional levels. In all equations there is the increase in output following the imposition of a fine, described earlier. This could simply reflect firms' relaxing more careful policies followed for the duration of the court case, but this can only be conjectured. The main interest lies in the change between Tables 3B and 5B for TSS: plants' output does seem to be responsive to exogenous changes in emissions limits in Table 5B, whereas they were not responsive to the limits themselves in Table 3B. For TSS at least, the instrumental variables approach sheds new light on firms' behavior.

As before, the question remains as to whether we can detect an effect on their actual emissions of firms' responses to exogenous legislation. Columns V (VI) of Tables 5A and 5B report the regressions of emissions on the predicted values from columns I and III (II and IV), as well as the exogenous component of the limits, lagged emissions, and the other regulatory variables. For BOD (Table 5A) there is no evidence that the investment response reported in column II actually affects emissions at all. A first suggested explanation is that firms announce as abatement capital projects that might have been taken on for other reasons and that have only a secondary, perhaps negligible, impact on emissions. This suggestion is in part inspired from the aggregate picture the data paint (see Figure 2): emissions have not significantly decreased over the period studied. There are other reasons why firms may announce investments that do not generate discernible subsequent reductions in emissions: a second is that firms may be building emissions control equipment which has not yet come on line. We try to rule out this explanation by using a reasonably long lag of *invest*. Thirdly, there may also be expectations of future regulations, green advertizing, or other factors increasing the cost to firms of emissions.

For TSS (Table 5B), the hypothesis that the output modulation reported in columns III and IV does reduce emissions cannot be rejected at the ten percent level. Exogenous changes in TSS limits do seem to be affecting firms' behavior enough to have a measurable impact on emissions.

Finally, in both the case of BOD and TSS, there is still a highly significant residual link between the instrumented limit and emissions, after accounting for the investment and output responses. The coefficient is of a magnitude of about 0.1 or 0.2 for BOD, and about 0.3 for TSS. This represents firms responding to the limits in ways undetected by our imperfect measurements of investment and output. This suggests that firms have ways of reducing emissions other than investing or modulating output: reallocating staff hours towards monitoring, better maintenance of pollution-control equipment or altering operational details within the plant. It is also noteworthy that the magnitude of the coefficients of the limit variables in the emissions equations are much lower than those reported in the "naive" regressions of Tables 2 and 3. This fact combined with the Hausman test (footnote 9) rejecting the exogeneity of the limits suggests that our approach through the full model was warranted.

9

4. Conclusions

Magat and Viscusi (1990) restrict attention to BOD emissions and suggest that firms' reactions to TSS regulations may be similar. Our results suggest that this may not be the case. For BOD, firms seem to respond by announcing investments, but these investments do not seem to have much effect on emissions. This in turn suggests that policy may have placed undue emphasis on the abatement technology itself (see the first paragraph of the introduction) rather than its results. Portney (1990, page 5), in the context of United States environmental regulation, observed:

> *"One finding is that much more attention has been devoted*
> *to ensuring that polluters get pollution equipment in place than to*
> *seeing that it is operated correctly."*

In contrast, changes in TSS limits seem to affect firms' short term output decisions, and the firms' adjustments are reflected in lower emissions.

The overall impression that the results give, of a relative lack of impact on emissions, is reinforced by the graphs of industry wide aggregates and ratios shown in Figure 2. Between 1985 and 1989, BOD and TSS emissions per unit of output remained relatively flat, as did output itself. Aggregate limits fell slowly over this period, but exceeded emissions, which fluctuated but showed no strong downward trend.

Previous work has drawn attention to the fact that United States environmental penalties are more severe than those in Canada, and that this may explain the perceived differences in firms' responses to legislation between the two countries. This lack of severity in Ontario may also explain the weakness of effect of the legislative variables used in this paper: emissions tend to increase after a fine is announced, for example. In particular, the lack of response of emissions to inquiries is in contrast with Magat and Viscusi's (1990) results for the United States. The results in general are consonant with those in Lanoie and Laplante (1994), who use stock market data to suggest that expected penalties associated with environmental infractions in Canada are not sufficiently severe to have a significant impact on firm behavior. An alternative explanation is that many of the firms were in compliance by a sufficiently large margin that changes in limits would not be likely to modify their behavior: more than three-quarters of the observations in the sample were in compliance.

On a methodological level, this paper addresses empirical issues that previous work in the economics of environmental regulation has not. First, it is necessary to

distinguish between exogenous changes in regulations (roughly speaking, those following from considerations of social costs and benefits) and endogenous changes in regulations (roughly speaking, those following from firms' past emissions or ability to abate). Second, it is possible to distinguish empirically between different modes of response on the part of firms. The data are imperfect, and the implementation of the empirical methodology can only be as successful as the data are accurate, but we hope that future work will be able to build on the methods used here. The ability to discern distinct firm responses to true regulator influence may in turn improve regulators' ability to improve environmental business law.

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Table 1 : Summary of Variables

Name	Definition/Units	Mean	St. Dev.	Source
BOD (emissions)	kg/day over 30 days	11029	12180	Ontario Environment Min
TSS (emissions)	kg/day over 30 days	3777	3165	Ontario Environment Min
BODlim	kg/day over 30 days	18741	20417	Ontario Environment Min
TSSlim	kg/day over 30 days	6002	4922	Ontario Environment Min
Invest	Can. $ '000 p.a.	606	1179	Pulp and Paper Canada
Output	m^3 of water per month	63104	58436	Ontario Environment Min
Summons	1 at 1st, 2 at 2nd...	0.551	1.047	Ontario Environment Min
Fine	1 at 1st, 2 at 2nd...	0.393	0.977	Ontario Environment Min
Inquiry	1 at 1st, 2 at 2nd...	4.401	6.998	Ontario Environment Min
Capa	Tons/month	58339	130730	Pulp and Paper Canada
Utilisation	Industry-wide Percent	0.957	0.014	Statistics Canada cat. 14-
Basin1-5	Indicator[a]			Ontario Environment Min
Region1-3	Indicator[b]			Ontario Environment Min
Season1-3	Indicator[c]			
Month1-11	Indicator[d]			
Subind1-3	Indicator[e]			Ontario Environment Min
Time	Period of observation.	36.5	13.863	

Notes : [a] Default: Ottawa River, 1: Hudson Bay, 2: Lake Superior, 3: Lake Huron, 4: Lake Ontario, 5: St. Lawrence

[b] Default: Centre-west, 1: Northeast, 2: Northwest, 3: Southeast

[c] Default: autumn (Sep-Oct-Nov), 1: winter (Dec-Jan-Feb), 2: spring (Mar-Apr-May), 3: summer (Jun-Jul-Aug)

[d] Default: December

[e] Default: Deinking/board/fine papers/tissue, 1: Kraft, 2: Sulphite-mechanical, 3: Corrugating

[f] "Report on Industrial Direct Discharges in Ontario" (1985-89)

Table 2 : POLLUTION EMISSIONS (BOD and TSS)

Coefficients/standard errors

	I	II	III	IV	V	VI	VII	
BODLIM	0.460**	0.230**	0.509**	0.295**				
	0.031	0.044	0.025	0.035				
TSSLIM					0.645**	0.469**	0.533**	
					0.053	0.061	0.046	
SUMMONS$_{t-1}$	295**	418**	240	355*	−151*	−61.0	−176*	−
	123	167	152	167	76.7	66.4	81.3	
FINE$_{t-1}$	171	317	186	341	−96.7	−76.3	−67.6	−
	131	181	164	186	83.2	73.1	89.5	
INQUIRY	−15.8	−5.21	13.593	29.537	8.97	5.54	4.71	
	14.3	21.2	19.97	22.87	6.89	5.68	7.61	
BOD$_{t-12}$		0.203		0.200**				
		0.033		0.032				
TSS$_{t-12}$						0.050*		0.
						0.024		0
CAPACITY		0.0226**		0.0171**		0.0077**		0.
		0.0054		0.0058		0.0014		0
UTILIZATION		757		714		−1567		−
		3548		3874		1267		
<u>dummies</u>								
basins	✓	✓			✓	✓		
regions			✓	✓			✓	
seasons	✓	✓			✓	✓		
months			✓	✓			✓	
subind	✓	✓	✓	✓	✓	✓	✓	
F	15.0	12.5	15.1	12.8	15.3	14.1	15.8	
r-square	0.80	0.80	0.71	0.75	0.81	0.85	0.81	
obs	720	720	720	720	720	720	720	

Table 3A : REACTION EQUATIONS - BOD

Coefficients/standard errors

DEPVAR[a]	I	II	III	IV	V	
	INVEST	INVEST	OUTPUT	OUTPUT	BOD	B
BODLIM	-0.0129**	-0.0137**	0.0214	0.283*	0.268**	0.4
	0.0040	0.0047	0.1481	0.136	0.045	0.
BODLIM$_{t-12}$	0.0133**	0.0117				
	0.0051	0.0065				
INVEST$_{t-12}$	-0.0228	-0.0466				
	0.0141	0.0272				
$\widehat{INVEST}_{t-12}$					-170	4
					252	1
$\widehat{OUTPUT}$					-18.7	8
					73.1	9
SUMMONS$_{t-12}$	10.6	34.7				
	20.8	38.3				
SUMMONS$_{t-1}$			-186	-211	263*	2
			573	692	115	1
FINE$_{t-12}$	1.48	13.4				
	22.2	43.6				

	I	II	III	IV	V	
FINE$_{t-1}$			936	**1701***	159	1
			604	**745**	130	1
INQUIRY$_{t-12}$	1.42	6.04				
	3.90	8.28				
INQUIRY			**207****	**268****	−8.55	1
			70.3	**94.4**	12.2	2
BOD$_{t-12}$					**0.222****	0.1
					0.032	0.
CAPACITY			**0.258****	**0.224****		
			0.024	**0.020**		
UTILIZATION	−60.4	−197	9825	10212		
	146	657	11930	18410		
dummies						
basins	✓		✓		✓	
regions		✓		✓		
seasons	✓		✓		✓	
months		✓		✓		
subind	✓	✓	✓	✓	✓	
F	14.0	13.1	21.0	18.1	13.8	1
r-square	0.05	0.06	0.94	0.86	0.84	0
obs	720	720	720	720	720	7

[a] DEPVAR: Dependent variable

16

Table 3B : REACTION EQUATIONS - TSS

Coefficients/standard errors

	I	II	III	IV	V	
DEPVAR	INVEST	INVEST	OUTPUT	OUTPUT	TSS	T
TSSLIM	-0.0108	0.0119	0.366	0.456	0.631**	0.5
	0.0192	0.0234	0.301	0.373	0.0513	0.
TSSLIM$_{t-12}$	-0.0197	-0.268				
	0.0214	0.030				
INVEST$_{t-12}$	-0.0329	-0.0519				
	0.0168	0.0281				
$\widehat{\text{INVEST}}_{t12}$					58.7	1
					137	1
$\widehat{\text{OUTPUT}}$					149**	21
					28.7	3
SUMMONS$_{t-12}$	12.4	39.8				
	21.7	38.6				
SUMMONS$_{t-1}$			21.5	-75.2	24.6	-5
			592	707	55.8	7
FINE$_{t-12}$	2.02	15.1				
	23.1	43.5				

	I	II	III	IV	V	
FINE$_{t-1}$			1029	**1702***	−67.1	**−1**
			628	**766**	60.4	**8**
INQUIRY$_{t-12}$	1.61	6.13				
	4.07	8.49				
INQUIRY			**187****	**198***	3.19	−6
			66.4	**86.9**	4.56	8
TSS$_{t-12}$					**0.0676****	0.
					0.0243	0.
CAPACITY			**0.253****	**0.245****		
			0.018	**0.018**		
UTILIZATION	−50.2	−174	10826	5896		
	144	652	12230	18300		
<u>dummies</u>						
basins	✓		✓		✓	
regions		✓		✓		
seasons	✓		✓		✓	
months		✓		✓		
subind	✓	✓	✓	✓	✓	
F	11.7	12.3	17.9	16.2	14.4	1
r-square	0.04	0.05	0.93	0.87	0.88	0
obs	720	720	720	720	720	7

18

Table 4 : First Stage Regression of Emissions Limits

	BOD	Std Error	TSS	Std Erro
PERIOD	**-339****	35.9	**-77.7****	6.71
CAPA*BASIN1	**4.62****	1.96	**3.46****	0.442
CAPA*BASIN2	**0.110****	0.003	**0.0187****	0.0005
CAPA*BASIN3	-0.00972	0.0129	**-0.0288****	0.0024
CAPA*BASIN4	**0.0468****	0.0040	**0.0180****	0.0008
CAPA*BASIN5	**28.6****	7.23	**29.6****	1.36
PERIOD*BASIN1	**460****	66.9	**50.8****	12.5
PERIOD*BASIN2	**670****	32.7	**125****	6.11
PERIOD*BASIN3	**92.6****	39.3	**226****	7.35
PERIOD*BASIN4	27.1	31.7	5.44	5.93
PERIOD*BASIN5	**229****	87.7	**77.7****	16.4
CONSTANT	**15348****	914	**3963****	171
r-square	0.86		0.92	
obs	720		720	

Table 5A : REACTION EQUATIONS with ENDOGENOUS LIMITS - BOD

Coefficients/standard errors

	I	II	III	IV	V	
DEPVAR	INVEST	INVEST	OUTPUT	OUTPUT	BOD	B
$\widehat{\text{BODLIM}}$	-0.00254	**-0.0198****	**0.155***	**0.232***	**0.0827****	0.2
	0.00244	**0.0059**	**0.072**	**0.099**	**0.0252**	0.
BODLIM_{t-12}	0.00336	**0.0166***				
	0.00450	**0.0078**				
INVEST_{t-12}	-0.0244	-0.0440				
	0.0154	0.0282				
$\widehat{\text{INVEST}}_{t-12}$					-75.9	8
					286	1
$\widehat{\text{OUTPUT}}$					-100	2
					67.1	**9**
SUMMONS_{t-12}	10.8	29.7				
	22.4	40.0				
SUMMONS_{t-1}			247	-34.4	**467****	63
			567	683	**146**	1
FINE_{t-12}	0.800	6.05				
	23.8	46.0				

20

	I	II	III	IV	V	VI
FINE$_{t-1}$			**1256***	**1923****	**418****	**4**
			613	**737**	**153**	**1**
INQUIRY$_{t-12}$	0.878	1.07				
	4.17	8.83				
INQUIRY			**133****	**178***	−5.74	**67**
			47.7	**70.5**	23.9	**1**
BOD$_{t-12}$					**0.280****	**0.2**
					0.031	0.
CAPACITY			**0.242****	**0.224****		
			0.019	**0.019**		
UTILIZATION	23.5	−135	9656	4975		
	164	670	11690	17050		
<u>dummies</u>						
basins	✓		✓		✓	
regions		✓		✓		
seasons	✓		✓		✓	
months		✓		✓		
subind	✓	✓	✓	✓	✓	
F	10.7	11.3	20.6	17.9	14.3	1
r-square	0.04	0.07	0.94	0.90	0.75	0
obs	720	720	720	720	720	7

21

Table 5B : REACTION EQUATIONS with ENDOGENOUS LIMITS - TSS

Coefficients/standard errors

	I	II	III	IV	V	
DEPVAR	INVEST	INVEST	OUTPUT	OUTPUT	TSS	T
$\widehat{\text{TSSLIM}}$	0.00311	0.0260	0.816**	1.34**	0.301**	0.3
	0.00857	0.0238	0.272	0.38	0.059	0.
TSSLIM_{t-12}	−0.0263	−0.0237				
	0.0188	0.0307				
INVEST_{t-12}	−0.0281	−0.0469				
	0.0158	0.0269				
$\widehat{\text{INVEST}}_{t-12}$					75.9	1
					132	1
$\widehat{\text{OUTPUT}}$					72.0*	99
					32.2	4
SUMMONS_{t-12}	12.4	42.8				
	20.7	37.0				
SUMMONS_{t-1}			238	−122	−99.4	−
			556	674	89.2	9
FINE_{t-12}	2.30	18.5				
	22.0	42.2				

22

	I	II	III	IV	V	
FINE$_{t-1}$			**1369***	**2013****	−48.5	1
			608	**733**	91.6	1
INQUIRY$_{t-12}$	1.75	6.19				
	3.97	7.92				
INQUIRY			**151****	**204****	0.187	−2
			46.9	**71.4**	9.82	9
TSS$_{t-12}$					**0.0764****	**0.0**
					0.0256	
CAPACITY			**0.245****	**0.231****		**0.**
			0.018	**0.016**		
UTILIZATION	−81.5	69.7	8393	2868		
	136	698	11630	17540		
<u>dummies</u>						
basins	✓		✓		✓	
regions		✓		✓		
seasons	✓		✓		✓	
months		✓		✓		
subind	✓	✓	✓	✓	✓	
F	10.1	11.2	22.4	19.0	15.6	1
r-square	0.04	0.06	0.94	0.90	0.57	0
obs	720	720	720	720	720	7

23

Figure 1 : Limits and Emissions for Four Mills

Figure 1a
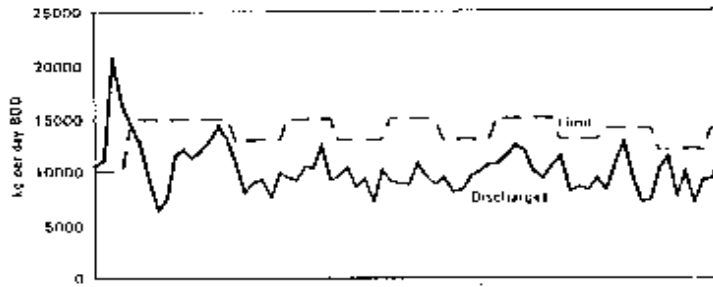
Figure 1b
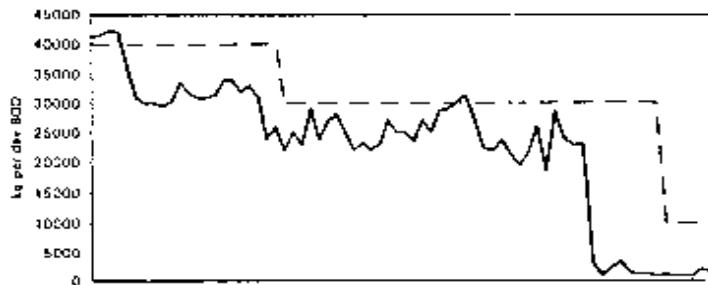
Figure 1c
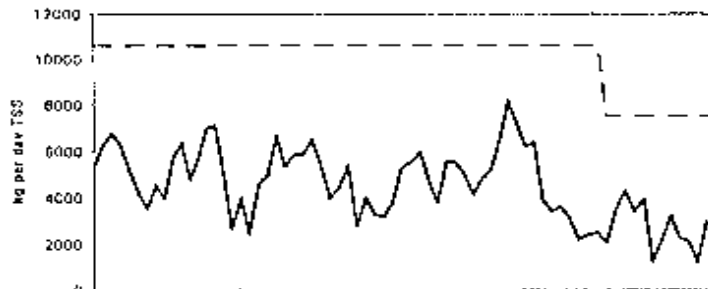
Figure 1d
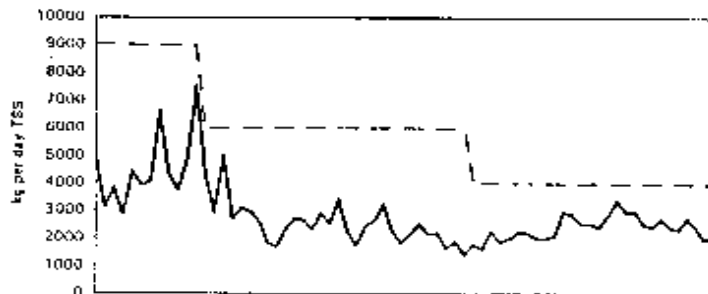
Figure 2 : Sample Aggregate Emissions, Output, and Limits

Total TSS Emissions and Limits (kg/day)

Total BOD Emissions and Limits (kg/day)

Industry Water Throughput (cubic m/day)

BOD and TSS / Industry output
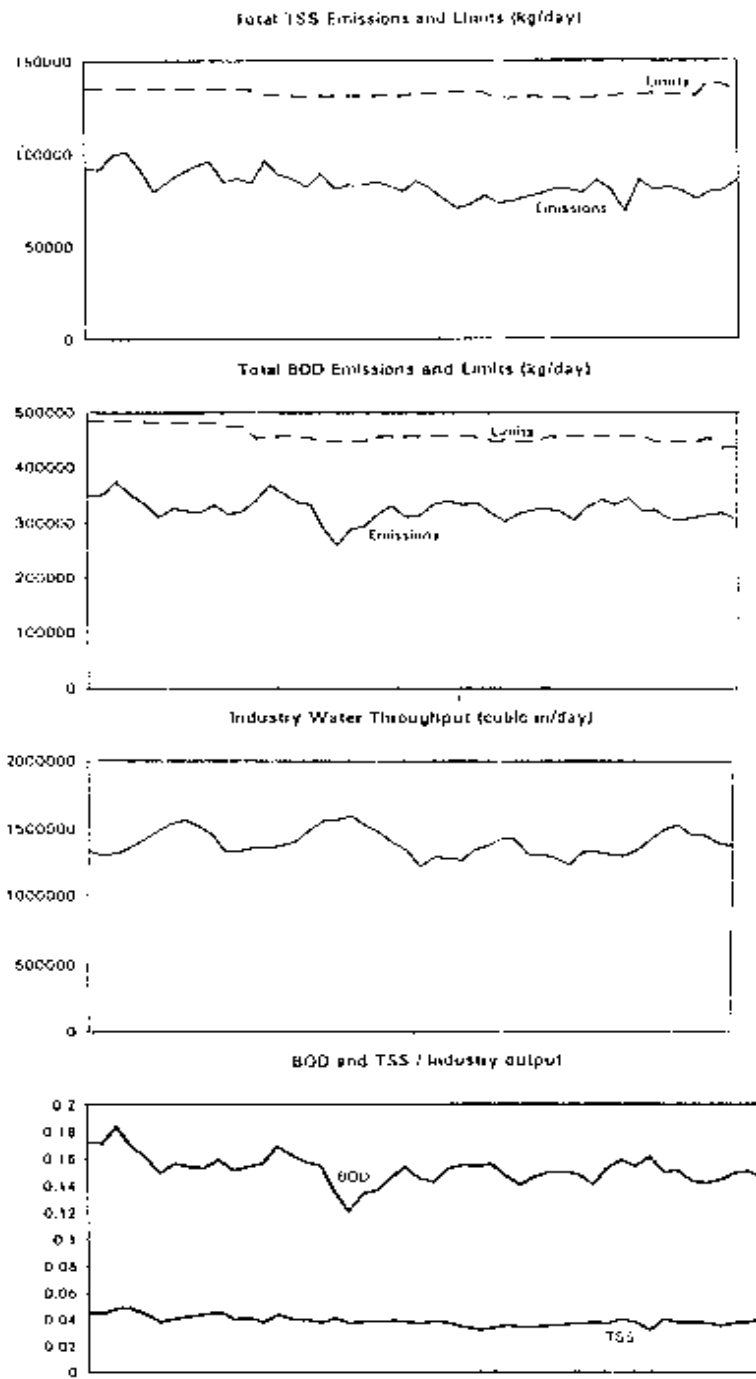
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