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W. Kip Viscusi

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EFFECTIVENESS OF THE EPA'S REGULATORY ENFORCEMENT: THE CASE OF INDUSTRIAL EFFLUENT STANDARDS*

WESLEY A. MAGAT and W. KIP VISCUSI
Duke University

I. INTRODUCTION

IN the almost two decades since the initial wave of social regulation, the academic literature documented very few, if any, instances of a health, safety, or environmental regulation being an unqualified success. Indeed, in most cases, the problem is even more fundamental. The typical analysis of government regulation found that the regulation did not even fulfill its primary mission, much less pass a more demanding benefit-cost test.

This absence of a well-documented case study of effective social regulation may be due, in part, to the particular set of regulations selected for analysis. There is certainly no inherent economic reason why such regulations cannot play a productive role in our economy. In the case of environmental quality, for example, the externality problems being addressed are not handled well by markets, implying that government regulation has at least the potential for playing a beneficial role. However, this potential will not be realized if the regulations are ill conceived or not effectively enforced, or if the environmental problem has no feasible solution.

A brief review of past regulatory experiences may be instructive to put in better perspective the Environmental Protection Agency's (EPA) water pollution control effort—the focus of this article. Most of these detailed evaluations have been done with respect to agencies other than the EPA.

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Although there have been some treatments of EPA regulations in the academic literature,[1] as well as some assessments within the government,[2] none of these evaluations have been undertaken with the same degree of statistical rigor and detailed empirical analysis that characterize analyses of health and safety regulations.

In large part, this lack of attention stems from the greater difficulty in constructing an environmental data base.[3] The decentralized nature of polluting activity, some of which is clandestine, makes pollution levels more difficult to monitor than compliance with, for example, safety cap requirements. These difficulties posed for external evaluation may also generate monitoring problems for the agency's enforcement staff. An important issue to be addressed here is whether the prolonged process required for us to amass a sound environmental data base for the purpose of external analysis is a reflection of underlying intrinsic difficulties in the monitoring and enforcement of EPA regulations.

The past assessments of health and safety regulations indicated that regulations were ineffective in promoting their objectives for two general reasons. The first is ineffectively designed regulatory policies. Thus, even though there is compliance with the regulatory requirements, little or no beneficial effect has been observed.

The seat belt requirements of the National Highway Traffic Safety Administration are one exhaustively studied instance. Since many drivers do not use seat belts, and those that do may alter their driving habits, the regulation has not produced the dramatic reduction in injuries and fatalities that the proponents of the regulation envisioned. Although some studies suggest no significant effect,[4] while others suggest a modest beneficial effect,[5] the overall implication is that seat belts have not pro-

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[1] Robert W. Crandall, Controlling Industrial Pollution: The Economics and Politics of Clean Air (1983); Paul MacAvoy, The Regulation of Air Pollutant Emissions from Plants and Factories (1981); and B. Peter Pashigian, Environmental Regulation: Whose Self-Interests Are Being Protected? 23 Econ. Inquiry 551 (1985), are excellent examples of such contributions.

[2] See, for example, U.S. General Accounting Office, Wastewater Dischargers Are Not Complying with EPA Pollution Control Permits (1983); and U.S. General Accounting Office, Water Pollution: Application of National Cleanup Standards to the Pulp and Paper Industry (March 1987).

[3] See Crandall, *supra* note 1, for discussion of many of the problems confronted with respect to air pollution data.

[4] For data supporting this conclusion, see Sam Peltzman, The Effects of Auto Safety Regulation, 83 J. Pol. Econ. 677 (1975).

[5] Among the best of the optimistic assessments of seat belt regulations is that of Robert W. Crandall and John D. Graham, Automobile Safety Regulation and Offsetting Behavior: Some Empirical Estimates, 74 Am. Econ. Rev. 328 (1984).

duced large reductions in injury and fatality rates because those designing the policy did not consider the crucial behavioral link involving drivers.

A similar effect has been observed with respect to the Consumer Product Safety Commission's safety requirements,[6] and, more generally, there is evidence that consumer product safety regulations are not sufficiently effective or extensive to substantially affect product safety. Manufacturers have complied with the regulatory standards, but consumer safety has not been enhanced.

Much the same story is true in the pharmaceutical area. Pharmacists and doctors have complied with the U.S. prescription requirements for drugs, with only occasional notable violations. Nevertheless, in terms of the effect of prescriptions on health, no significant health effects of these requirements have been observed either for the United States or elsewhere in the world.[7]

The second reason for regulatory failure is the lack of enforcement. For example, the Occupational Safety and Health Administration (OSHA) has extensive regulatory requirements but traditionally enforced them quite laxly. Indeed, the inspection rates are so low (less than one inspection per century per firm) and the penalties are so small (only $6 million annually) that there are few incentives for compliance. The result is, at best, a very modest effect on safety outcomes.[8]

The EPA water pollution regulations—the focus of this study—represent an interesting departure from past patterns of regulatory failure. First, the nature of the regulations—discharge limits—relates directly to the policy objective of controlling pollution, and there is no potential for offsetting behavioral responses. If the pollution standards are binding and enforced, they should improve water quality. Second, the enforcement effort is so extensive that enforcement should affect firms' compliance. In the pulp and paper industry, which we will analyze, the EPA averages roughly one inspection annually per major pollution source. In addition, firms are required to file monthly discharge monitoring reports, providing one of the most thorough monitoring capabilities of any health, safety, or

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[6] See W. Kip Viscusi, Consumer Behavior and the Safety Effects of Product Safety Regulation, 18 J. Law & Econ. 527 (1985).

[7] For supporting data, see Sam Peltzman, The Health Effects of Mandatory Prescriptions, 30 J. Law & Econ. 2 (1987).

[8] The most extensive analysis is that in W. Kip Viscusi, The Impact of Occupational Safety and Health Regulation, 1973–1983, 17 Rand J. Econ. 567 (1986). Analyses of earlier periods of OSHA enforcement are provided in Ann P. Bartel & Lacy Glen Thomas, Direct and Indirect Effects of OSHA Regulations, 28 J. Law & Econ. 1 (1985), and in Robert S. Smith, The Impact of OSHA Inspections on Manufacturing Injury Rates, 14 J. Human Resources 145 (1979).

environmental agency. Prior to the 1987 revisions of the Clean Water Act,[9] one potential weak link was that EPA officials could not directly assess penalties for noncompliance. They could, however, seek the imposition of substantial penalties through court action.

In the subsequent sections, we describe the nature of the EPA enforcement of water pollution regulations in the pulp and paper industry and the original data base we created for this study. Using information from EPA and industry sources, we constructed a longitudinal data base by firm, permitting a detailed evaluation of the effects of EPA inspections and their associated enforcement actions on the behavior of pulp and paper plants. As the empirical results will indicate, we find diverse evidence of significant EPA effects on the polluting and reporting activities of firms in the pulp and paper industry.

II. Enforcement of Water Pollution Regulations in the Pulp and Paper Industry

In choosing to study the enforcement of environmental regulations by the U.S. Environmental Protection Agency and by state environmental agencies, we could have chosen several different media. Only for water pollution was it possible to find a relatively complete data base of pollution discharge measurements by source and a data base on enforcement actions at these same plants. The same informational base that permits us to provide a sound empirical analysis also assists the EPA in its effort to monitor and enforce compliance. Overall, it is believed that more than 90 percent of all major water discharges are in compliance with EPA standards, as contrasted with estimated compliance rates as low as 20 percent for toxic and hazardous substance regulation.[10] Thus, one should be cautious in generalizing from the EPA's record in water pollution to other pollution problems. The investigation reported here should be regarded as an examination of an important and representative component of one of the EPA's most effective regulatory programs.

Since the data on inspections were much more complete than on other enforcement actions, such as administrative orders, notices of violations,

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[9] Section 314 of the Federal Water Quality Act of 1987 authorizes the use of administrative penalties that can be assessed directly by the EPA.

[10] For supporting data, see Cheryl Wasserman, Improving the Efficiency and Effectiveness of Compliance Monitoring and Enforcement of Environmental Policies, United States: A National Review, Organization for Economic and Cooperative Development (1984).

warning letters, and telephone calls,[11] we focus on the relationship between plant inspections and water pollution discharge levels. This emphasis on inspections also accords with our a priori views regarding the role of different enforcement instruments since inspections are one of the most important components of any enforcement program and thus merit special attention.

To measure the relationship between inspections and subsequent compliance, we examine one industry, pulp and paper. This industry is the country's largest discharger of conventional pollutants, such as organic waste and sediment,[12] and has a long history of water pollution enforcement efforts by various governmental agencies. There is no reason to believe that the effectiveness of inspections in the pulp and paper industry differs markedly from that in other industries regulated by the EPA. Also, by concentrating on one industry, we avoid the problem of controlling for interindustry differences in the stringency of regulations, differences in the nature of the pollution, and differences in the technologies for compliance.

The EPA traditionally focuses on the control of Biological Oxygen Demand (BOD) because it is the most damaging conventional pollutant discharged by the pulp and paper industry.[13] Most inspections examine BOD levels in addition to other pollutants of interest for a given plant. Also, the technologies that control BOD discharges tend to reduce the levels of other pollutants, which means that the relationship between inspections and BOD discharge reductions ought to be similar to the relationship between inspections and discharge reductions for other pollutants.

The pulp and paper industry consists of hundreds of companies operating plants in thirty states within seven of the ten EPA regions in the country. The EPA Permit Compliance System (PCS) data base described below lists 418 separate sources of pollutant discharge in the industry. Biological Oxygen Demand, Total Suspended Solids (TSS), and the pH levels of discharges are the three main conventional pollutants controlled, although in recent years Congress has initiated new regulatory efforts to also control toxic pollutants.

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[11] One reason for the completeness of the data on inspections is that the EPA regional offices are not credited with conducting an inspection until it is coded into the central data base. See U.S. Environmental Protection Agency, Office of Water Enforcement, NPDES Inspection Manual, at iii (June 1984).

[12] U.S. General Accounting Office, Water Pollution, *supra* note 2, at 8.

[13] BOD is the standard measure of the organic pollutant content of water.

If the EPA set water pollution standards in the same manner as seat belt regulations or OSHA standards, a description of the regulatory constraints would be straightforward. In the seat belt and OSHA cases, firms face well-defined requirements on the technology or work environment. All firms must comply with the same set of regulations, such as ensuring that punch presses have the specified guards. There has been little change over time in the nature of the standards, except that some new regulations have been added. In contrast, EPA water pollution standards involve permissible pollution amounts that vary across firms and over time.

The 1972 Federal Water Pollution Control Act amendments set the framework for regulation on industrial water pollution. The act required that all sources discharging into the navigable waters of the country meet discharge standards based on the application of the "best practicable control technology" (BPT) by July 1, 1977, while complying with standards based on the "best available technology economically achievable" (BAT) by July 1, 1983.

In 1977 the act was amended again, pushing back the 1983 deadline to July 1, 1984, and substituting a more complicated requirement. Conventional pollutants such as BOD and TSS were to meet standards based on the adoption of the best conventional technology (BCT), while toxic pollutants were to meet standards based on the best available technology (BAT).

The final BPT and BAT standards for various subcategories of the pulp and paper industry were promulgated on three separate dates: May 9, 1974; May 29, 1974; and January 6, 1977. The final BCT standards were issued on December 17, 1986, and left the BPT standards for BOD control unchanged. The BPT standards generally set limitations on the quantities of BOD that a plant could discharge per pound of pulp or paper produced.[14] However, the allowable discharges of BOD from each source were derived by multiplying this effluent limitation by the number of pounds of pulp or paper produced per day at the plant. This latter number formed the basis of the National Pollutant Discharge Elimination System (NPDES) permit required of each discharger. Since our empirical study covers the period from the first quarter of 1982 through the first quarter of 1985, the NPDES permits restricting BOD discharge were based on the 1977 BPT standards.

The EPA possesses the authority to issue the NPDES permits, but the authority has been delegated to thirty-seven states meeting specified fed-

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[14] For a formal description and analysis of the BPT rule-making process, see Wesley A. Magat *et al.*, Rules in the Making: A Statistical Analysis of Regulatory Agency Behavior (1986).

eral criteria. States approved to issue NPDES permits also assume responsibility for their enforcement, which means inspecting the plants and taking action against sources found to be out of compliance. For states not approved to run their own permit systems, the EPA issues and enforces the permits.

An important aspect of the permit process should be emphasized. The EPA and the states do not set uniform permit levels irrespective of the industry characteristics associated with the pollution source. Each standard is industry specific and represents pollution levels that are potentially achievable with available technologies.

Each source must regularly measure its pollution discharge levels and report its actual discharges of each pollutant in its permit on a monthly basis through a Discharge Monitoring Report (DMR). If a source is out of compliance with the effluent standards in its permit, it is also required to file a noncompliance report. The states and EPA regional offices send the DMRs to the EPA, which enters them into the PCS data base to serve as a basis for tracking compliance. In addition, the EPA requires that Quarterly Non-compliance Reports (QNCR) be filed by each state and region to identify sources out of compliance. In the empirical study that follows, we use the reported BOD discharge levels in the DMRs to measure the effects of inspections on BOD discharge levels.

Because the sources are required to report their pollutant discharge levels on a monthly basis, the on-site inspections play a somewhat different role than inspections carried out by other regulatory agencies, such as an OSHA inspection of an industrial site. The latter inspections constitute the primary basis for the agency to check compliance with its regulations and to have a visible presence in the workplace. In contrast, EPA or state-run inspections of industrial water pollution sources create a similar visible presence, but they provide only a secondary source of information about compliance because the monthly DMRs address the compliance question directly. Some NPDES permit inspections do test whether the DMR discharge levels are reported accurately and honestly, and they provide an incentive for firms to submit DMRs more frequently.

The difference between EPA inspections and OSHA inspections has also been narrowing over the years. Although the Bureau of Labor Statistics does not release the mandated injury reports to OSHA for compliance purposes, OSHA now gathers this information through on-site records checks to target its inspections. This procedure represents a partial and more time-consuming variant of the DMR process. Firms with good injury records are exempt from OSHA inspections.

The EPA inspections directly address one or more of the following items: the existence of an up-to-date permit, the installation of the abatement equipment necessary for compliance with the permit, management plans and practices, the preparation and maintenance of records, the correct operation of the abatement equipment, and the conduct of sampling and sample analysis. As a recent EPA report to the Organization for Economic and Cooperative Development (OECD) explains, "Despite widespread self-monitoring, inspections remain the backbone of agency compliance monitoring programs. . . . inspections are the government's main tool for officially assessing compliance, and for assuring quality control and lending credibility to self-monitoring programs. The independent evaluation provided by a government inspection is the key."[15]

The EPA carries out three main types of inspections—compliance sampling inspections, compliance evaluation inspections, and performance audit inspections. Compliance sampling inspections require approximately thirty workdays of time to complete and involve actual sampling of the effluent at the plant, as well as an examination of the company's record-keeping system, its testing procedures, and its treatment system. In contrast, the compliance evaluation inspections take only about three workdays to complete. They involve no sampling, but the inspectors do examine the company's treatment facilities, monitoring methods, and records. The performance audit inspections require about twelve days to complete and consist of the same practices used in the compliance evaluation inspection, plus observation of the permittee going through the steps in the self-monitoring process from sample collection and flow measurement through laboratory analyses, data workup, and reporting. In addition, the performance audit inspector may leave a check sample for the permittee to analyze.

Based on the discharge reports in the DMRs and in the QNCRs, as well as on the findings of inspections, the EPA or the approved state agencies take enforcement actions against violators. Informal actions include telephone calls, warning letters, and notices of violation, as well as inspections. If these measures do not achieve the intended results, the control agencies can proceed with formal actions such as administrative orders, permit revision, formal listing of companies as ineligible for government contracts, grants, and loans; and, finally, civil and criminal judicial responses.

Court action is a lengthy process involving the Justice Department that is started only as a last resort. Under Section 309(e) of the 1977 Clean Water Act, civil penalties could have been awarded up to a level of $10,000 per day, while criminal penalties could have ranged from $2,500

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[15] Wasserman, *supra* note 10, at III-7.

to $25,000 for the first violation and up to $50,000 for the second violation.[16] In addition, first violations could have led to imprisonment of up to one year, with up to two years of imprisonment for the second violation. During the period from January 1, 1975, to July 1, 1985, the EPA commenced 64 judicial actions in the pulp and paper industry. Of these, 42 cases resulted in fines, and four were still pending at the end of the period. The fines varied from $1,500 to $750,000, with an average of $89,437. Because the regions lacked the incentives to report regularly enforcement actions other than inspections into the PCS data base, we concentrate our study on the effectiveness of the inspections on bringing firms into compliance with their permits.

The inspections variable is intended to be a proxy for the overall enforcement effort associated with an inspection and all subsequent enforcement actions. The financial penalties associated with noncompliance may be much greater than is indicated by the fines actually assessed since these fines do not reflect the potential losses due to noncompliance. Indeed, to take the extreme case, if the sanctions were so great that enforcement effort was fully effective, no instances of noncompliance or penalty assessments would be observed. The enforcement measure to be used in the regression equations should reflect the expected sanctions, not the level of sanctions observed after the deterrence effect has operated. The EPA inspections variable will serve both as a measure of the formal contact of the EPA with each firm as well as the institutional trigger that will generate additional enforcement sanctions for noncomplying firms.

III. THE SAMPLE AND THE VARIABLES

The Data Base

The PCS data base, which we utilize in our analysis, lists 418 separate sources in the pulp and paper industry in its Inspections file. Under half of these sources—194—had BOD discharges. Of this group, seventy-seven submitted DMR measurements for BOD discharge into the Measurement file. As a result, the data set that we used includes seventy-seven of the 194 major sources of BOD in the pulp and paper industry.

The information that is missing was not governed by an entirely random process. The sources that were not included either did not enter their DMRs into the PCS data base, or they did not submit DMRs including

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[16] Under the Federal Water Quality Act of 1987, the maximum civil penalty rose to $25,000 per day and the maximum criminal penalty increased to $50,000 for the first violation and $100,000 for the second violation.

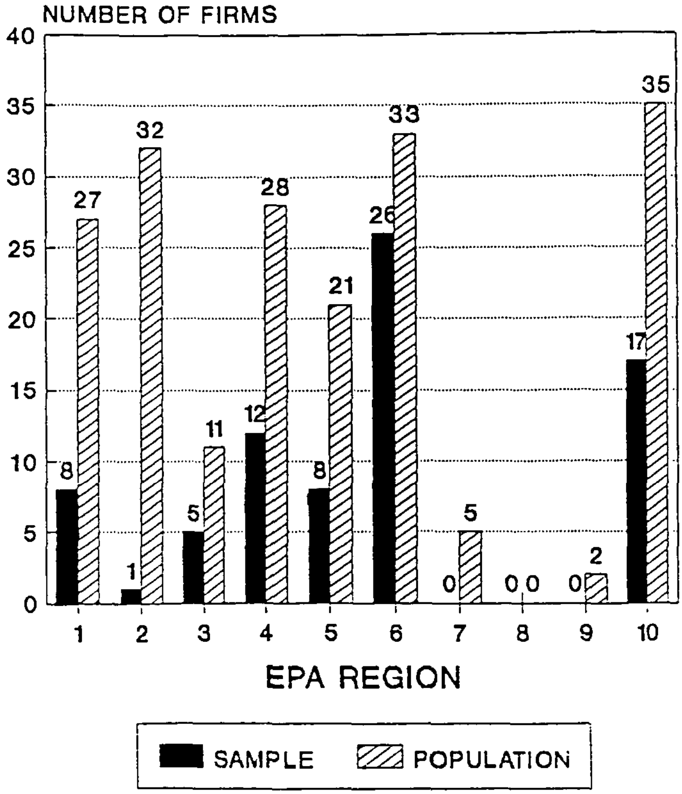

Figure 1.—Sample and population firms by EPA region; $N = 194$

BOD measurements during the period under study, or they discharged pollutants other than BOD.

The principal factor affecting the missing sources is the time required before the records could be computerized. Officials at the EPA believe that most of the other sources not in the PCS data base did submit DMR data to the EPA or the states, but they were not entered into the PCS data base because the system was not yet operational and the states and regions were not required to enter the data.[17] This view is consistent with the regional patterns of sources included in our data base. Seven of the nine EPA regions with pulp and paper mills are represented in our data base (see Figure 1). In addition, nineteen of the twenty-seven states with

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[17] This view is based on discussions with EPA analysts most familiar with the PCS data base and the pulp and paper industry. Even though some of the states did not have the capability to enter the DMR data into the PCS data base, they regularly screened the data and summarized them in the QNCRs.

TABLE 1

NUMBER OF FIRMS IN SAMPLE AND POPULATION BY STATE

State	Firms in Sample	Firms in Population
Alaska	1	2
Alabama	0	10
Arkansas	8	8
California	0	2
Florida	8	9
Idaho	1	1
Iowa	0	2
Illinois	2	3
Indiana	1	4
Kentucky	3	3
Louisiana	9	13
Maryland	0	1
Massachusetts	3	16
Minnesota	1	5
Missouri	0	3
New Hampshire	5	11
New Jersey	1	10
New York	0	21
North Carolina	0	4
Ohio	4	9
Oklahoma	3	3
Oregon	7	14
Pennsylvania	5	10
Puerto Rico	0	1
Tennessee	1	2
Texas	6	9
Washington	8	18

pulp and paper mills are captured in the sample (see Table 1). The principal selectivity process is that some states and two EPA regions did not computerize their DMR reports by 1982:1. If computerization is positively correlated with more effective enforcement (which we have no way of knowing and no a priori reason to suspect), our empirical results will tend to overstate the effectiveness of water pollution enforcement overall. However, it should be noted that, even if there is a selectivity bias, it should create much less bias than a scenario in which the firms missing from the data base were determined on a firm-by-firm basis based on the quality of the DMR data supplied by each firm.

The firms in our sample tend to be larger than those without data. Available data on 170 out of the 194 pulp and paper plants show that the mean output level of firms in the sample is 62 percent higher than those outside the sample and that 54 percent of the industry output is produced by the firms in our sample. We do not have the data to measure the share of industry pollution discharges from our sample, but to the extent that output levels are correlated with pollution discharge levels, about half of the industry BOD discharges would have been produced by the firms in our sample.

Thus, based on the available evidence, we conclude that our sample comprising 40 percent of the firms and 54 percent of the output in the industry is representative of the entire pulp and paper industry, except to the extent that there is some relationship between the effectiveness of inspections and either firm size or the decision by states or EPA regional offices to enter discharge data in the PCS data base. If these two factors are for some reason correlated with the effectiveness of inspections, then our results need to be interpreted as estimates of the response to EPA inspections of firms whose discharge levels are regularly reported to the EPA's national data base.

The firms represented in our sample are all located within Standard Industrial Classification (SIC) 26. We have further divided this industry characterization into five four-digit SIC codes (2611, 2621, 2631, 2648, and 2661).[18] For the period from the first quarter of 1982 through the first quarter of 1985 there were 276 inspections of the sources in the sample, of which 43 percent were compliance sampling and 57 percent were compliance evaluation.

In this analysis we use calendar quarters as the unit of analysis. Only rarely was there more than one inspection for a given source in the same quarter. Despite the requirement that sources report DMRs every month to the state enforcement agency or the EPA, for the reasons explained above, some DMR measurements are missing for the sources in our sample. In constructing the quarterly BOD measurements for our statistical analysis, we interpolated to fill in missing values and used averages of the BOD discharge levels within a quarter as the quarterly average BOD discharge levels.

Although the EPA analysts to whom we talked were confident that most of the discharge measurements in the DMRs were reported accurately, permittees do have several opportunities to cheat. They may choose not to report discharge measurements during months with unusually high discharge levels. This behavior would lead to some smoothing of the pattern of reported discharges, eliminating the top end of the

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[18] The sample of seventy-seven sources matches the full set of pulp and paper sources fairly closely in terms of the distribution of sources across regions, the mix of products across the four-digit SIC codes, and the frequency of plant inspections in each quarter. The only differences of note were that regions 6 and 10 are somewhat overrepresented, while region 2 is underrepresented, and the sample firms were inspected about 25 percent more often.

distribution. More active attempts to mislead EPA include altering the contents of the sample being tested, falsely calibrating the test instruments, and recording false measurements in the DMRs.

Despite these possibilities for sending the EPA misleading or false DMR discharge statistics, there are several incentives to report honest information in the DMRs. The EPA follows the policy of attempting to inspect all major sources at least once a year. Compliance sampling inspections would detect whether most of the reported measurements were inconsistent with the measurements from the inspections, but they could not detect whether outliers were removed from the reports. Compliance evaluation inspections would detect the absence of the required abatement equipment, but would be less useful in evaluating whether the abatement systems were being operated correctly. Of course, the penalties for noncompliance and fraud in reporting also create incentives for truthful reporting of discharge measurements. The possibility of leaks to EPA by disgruntled employees makes this last incentive more compelling to firms considering manipulating their DMR data.

Taking into account the possibility that the DMR measurements may measure true compliance status with some error, it is still instructive to ascertain how well firms comply with the effluent regulations. Recently, the Environmental Protection Agency[19] issued a study of compliance by all the major pulp and paper mills (SIC 2611, 2621, 2631) in the eight southeastern states comprising EPA region 4 over the period from the second quarter of fiscal year 1982 through the first quarter of fiscal year 1984. Eighty-two percent of the measurements fell within the permitted bounds. This compares with 75 percent of the measurements from the pulp and paper firms in our sample being in compliance. The EPA further defines significant noncompliance for BOD as violations of the monthly average permit limits for any two months in a six-month period that exceed the limit by 40 percent, or violations of the monthly average limits for any four months in a six-month period. Using this definition, 94 percent of the measurements indicated discharge levels not in significant noncompliance. The study also showed that four out of the fifty-six mills created most of the instances of significant noncompliance.[20]

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[19] U.S. Environmental Protection Agency, Study of Pulp and Paper Industry in Region IV (1986).

[20] In light of the low fines assessed and the relative infrequency of inspections, some readers may question the reasons for the high compliance rates. While our study addresses only the incremental effect of inspections and associated enforcement actions on compliance, we can speculate on the explanation for the high base rate of compliance.

In a well-functioning regulatory system, one would not expect to see frequent use of strong sanctions, such as fines, for firms complying with regulations in order to avoid the sanctions. It is only necessary that firms *believe* they will be sanctioned if they fail to

TABLE 2

MEANS AND STANDARD DEVIATIONS OF VARIABLES DESCRIBING SEVENTY-SEVEN PLANTS IN SAMPLE (1982:1–1985:1)

Variable	Mean	Standard Deviation
MQAVG (pounds per day)	5,758.288	8,919.173
MVIO (1 = out of compliance)	.252	.434
IQTR1 (1 = inspection one quarter prior to measurement)	.248	.432
IQTR2	.273	.446
IQTR3	.273	.446
IQTR4	.281	.450
IQTR5	.300	.458
IQTR6	.295	.456
REGN1 (1 = source located in region 1)	.095	.293
REGN2	.002	.039
REGN3	.064	.244
REGN4	.154	.361
REGN5	.039	.193
REGN6	.435	.496
REGN7	.000	.000
REGN8	.000	.000
REGN9	.000	.000
REGN10	.213	.410
SIC11 (1 = pulp mill)	.241	.428
SIC21 (1 = paper mill excluding building)	.432	.496
SIC31 (1 = paperboard mill)	.253	.435
SIC48 (1 = 7 stationary products)	.014	.117
SIC61 (1 = building paper or paperboard mill)	.048	.214
TONS (daily output rate)	794.156	587.083

Sample Characteristics

Table 2 summarizes the means and standard deviations for the sample of the variables used in our analysis. The sample is a pooled time series and cross section of seventy-seven plants followed on a quarterly basis from 1982:1 to 1985:1. The first two variables represent the pollution outcome measures that will be of primary interest as dependent variables

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comply. Despite their infrequent use, there are a variety of punishments that the EPA can impose, short of judicial fines. For firms that do not comply, the agency can raise the frequency and intensity of inspections, write permits using stricter interpretations of the regulations (for example, using average rather than maximum production rates to calculate allowed discharge levels), deny operating permits, subject the firm to bad publicity, and engage in protracted haggling, and possibly prolonged litigation, which imposes high costs in terms of legal fees, management time, and general uncertainty about being allowed to operate.

in different equations. The variable MQAVG is a continuous measure of the extent of pollution. It measures the number of pounds of BOD discharged per day, where this amount is averaged over the quarter. Although the amount of pollution is a variable of substantial economic interest, it is not the sole variable of concern. Different firms may have different permitted pollution levels so that, for example, a large plant may be in compliance with a high BOD level whereas a small plant may be in violation of its permit even though its discharge is less. Analyzing the effect of inspections on total discharges is, however, one of the most important ways of assessing the benefits of the EPA's regulatory enforcement.

The second pollution variable, MVIO, is a discrete zero or one variable that takes on a value of one if the pollution source is in noncompliance with its BOD discharge permit in any of its monthly measurements that quarter. This variable best captures whether the firm's performance is in compliance with its water pollution permit, but it does not reflect the extent of noncompliance. Unfortunately, it is not possible to construct a reliable measure of the amount of pollution in excess of the permitted amount since data pertaining to the level specified in the permit are not available from the PCS data base. Instead, we are restricted to MQAVG and MVIO rather than a hybrid of a continuous pollution measure and discrete compliance measure.

The next set of variables is a series of zero or one dummy variables pertaining to whether the firm was inspected in a particular quarter. The variable IQTRJ is of the general form in which it takes on a value of one if the pollution source received an inspection J quarters previous to the pollution measurement in the current quarter, where J takes on a value from one to six. It is quite striking that the rate of inspection is quite high, on the order of 25–30 percent per quarter.

This relatively high inspection rate distinguishes the EPA enforcement effort from that of OSHA. Not only does the EPA receive regular discharge monitoring reports from firms, but it also undertakes water pollution inspections at a rate of about one inspection annually per major pollution source. In contrast, OSHA has no automatic data feedback mechanism, and it has a much more sporadic inspections effort. In OSHA's early years, some analysts equated OSHA's inspection frequency to other rare events such as the annual chance of seeing Halley's comet. At present, the OSHA inspection rate is much lower than this amount—on the order of 1/200 for each firm in any year.[21] The intensity of

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[21] See W. Kip Viscusi, Reforming OSHA Regulation of Workplace Risks, in Regulatory Reform: What Actually Happened 259 (L. Weiss and M. Klass eds. 1986).

EPA inspections consequently dwarfs that of OSHA inspections so that there is no reason to believe that the lack of efficacy of OSHA's minimal enforcement operation has any adverse implications for the EPA's chances of success.

The variables of the form REGNJ are zero or one dummy variables for the EPA region J in which the plant is located. These variables will be utilized to ascertain whether there are any important regional differences in pollution patterns. It should be noted that there are no pulp and paper mills located in three of the EPA regions (7, 8, and 9) and there are no PCS data on mills in region 2.

The next set of six variables are of the form SICJK, which represents a dummy variable for the plant's four-digit SIC industry code 26JK, where JK takes on the values 11, 21, 31, 48, and 61. Although all firms are in the pulp and paper industry, it was desirable to also include refined industry-group dummy variables that reflect the firm's specific operations and technology. For example, pulp mills (SIC 2641) have different operations than converted paper plants (SIC 2649).

The final variable listed is TONS. It measures the number of tons of pulp and paper produced daily at the plant. Unlike the other variables in the data set, this variable was not included in the PCS data base. We matched each firm to a capacity measure using data provided in a published industry directory.[22]

IV. THE EFFECT OF INSPECTIONS ON POLLUTION

The major purpose of this article is to measure empirically the effects of inspections, along with their associated enforcement actions, on the behavior of firms in the pulp and paper industry. We will concentrate on an econometric approach that relates the conduct of an inspection in a given quarter to two measures of the firm's BOD abatement effort: (1) its absolute rate of effluent discharge (MQAVG), and (2) whether its discharge rate falls below its permitted level (MVIO). We also examine the effect of plant inspections on reducing the incidence of nonreporting of DMR data. To the extent that firms purposely refrain from reporting discharge levels during periods of noncompliance, the first two measures of the effect of inspections would be biased toward less effect than what actually occurred. This third measure allows us to determine whether inspections improved the completeness of the EPA's discharge monitoring system that presumably lead to more discovery of noncompliance and, through

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[22] See Lockwood's Directory of the Paper & Allied Trades (1983 ed.).

subsequent enforcement efforts, further reductions in pollutant discharge levels.

Empirical Framework for Measuring Abatement Effects

The underlying economic framework is straightforward, as pollution levels are governed by a capital investment process relating to the pollution control technology, as well as by the efficiency levels at which the abatement equipment is operated. The role of EPA inspections is to raise the expected cost of noncompliance, boosting the incentives for pollution reduction and compliance with the permit. Since the underlying theoretical basis is straightforward, we will proceed directly to the estimating equations.[23]

The equations to be estimated will be of the same general form whether the pollution variable is MQAVG or MVIO. To illustrate this general form, let POLLUTION_{it} be the value of the pollution variable MQAVG or MVIO for pollution source i in period t. Some additional notation is needed before we can write down the equation to be estimated. The variable IQTRJ_{it} is the zero or one inspection variable for whether pollution source i was inspected in period $t - \text{J}$, TONS_i is source i's capacity measure, SIC_i is a vector of four-digit SIC-code dummy variables for pollution source i, REGN_i is a vector of dummy variable for the EPA regions for source i, and QUARTER_t is a vector of dummy variables for the quarters. The resulting estimating equation is of the form

$$\begin{aligned}\text{POLLUTION}_{it} = \alpha &+ \beta_1\text{POLLUTION}_{it-4} + \sum_{k=1}^{n} \gamma_k \,\text{IQTR}_{t-k} \\ &+ \beta_2\text{TONS}_i + \beta_3\text{SIC}_i + \beta_4\text{REGN}_i \\ &+ \beta_5\text{QUARTER}_t + v_{it},\end{aligned}$$

where v_{it} is a random error term. In the case of the continuous pollution measure, MQAVG, ordinary least squares is the appropriate estimator, whereas for the discrete compliance variable, MVIO, a logistic estimation procedure is employed. With some modifications, this equation is in the same general spirit as similar equations estimated for safety regulations.[24]

The first variable included is the lagged dependent variable, with the noteworthy distinction that the lag is four quarters rather than one. The

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[23] The model implicit here is articulated more fully for the analogous job safety case in W. Kip Viscusi, The Impact of Occupational Safety and Health Regulation, 10 Bell J. Econ. 117 (1979). More generally, see Richard Posner, Economic Analysis of Law (3d ed. 1986).

[24] The equation bears closest similarity to those in Viscusi, *supra* note 8.

variable POLLUTION_{it-4} is a proxy for the firm's stock of capital related to pollution control and for the general character of its abatement technology. Firms with high levels of pollution in the past are likely to continue to have high levels in the future because the nature of their control technology makes it costly to achieve pollution reductions. A four-quarter lag is utilized rather than a single-quarter lag to capture the seasonality that often plays an important role in a firm's operations. The products produced, stream flow conditions, and the pollution permit amount may vary by season.

The lagged dependent variable serves an additional role with respect to regression-to-the-mean effects. It is possible that firms with an abnormally high pollution level in period t due to stochastic factors will be inspected in period $t + 1$ and improve their performance compared with period t, wholly apart from any true inspection effect. Because the lagged values captures pollution levels, or compliance status, four quarters earlier, however, they are less susceptible to leading to inspection variable results that simply capture regression-to-the-mean effects.

The next set of variables is a distributed lag on past EPA inspections. Evidence for OSHA suggests that there is generally a lag before firms can make the required capital investments to alter their performance level.[25]

Even if compliance only entails changes in operating procedures following an inspection, an effect may not be apparent until the next quarter. Consider a situation in which the firm files its DMR data for the first month of the quarter in the middle of the second month of the quarter. Even if the EPA undertakes an inspection immediately, which is not usually the case, the sampling will not be completed until the middle of the final month of the quarter. Thus, under this best-case scenario only half a month, or one-sixth, of the pollution discharges for the quarter will be affected by the inspection. Because of time lags before the EPA receives the DMR data, the time needed before the EPA can schedule an inspector to make a plant visit, the rather lengthy inspection process, and the time needed before the EPA makes its report to the firm and the firm can take action on it, no contemporaneous effect is expected.

Before requiring that any inspection effect enter with a lag, we empirically tested for whether the inspection variable led to a contemporaneous negative effect on pollution. Rather than a negative effect, we observed a strong and statistically significant positive influence, consistent with the reverse causality hypothesis. We explored the causality issue in greater detail. Based on a Hausman[26] specification test, we were able to reject the

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[25] *Id.*

[26] Jerry Hausman, Specification Tests in Econometrics, 46 Econometrica 1251 (1978).

hypothesis that the IQTR_{it} variable is exogenous. Attempts to replace IQTR_{it} ($t = 0$) by an instrumental variable estimator also led to positive coefficients, suggesting that the primary relationship between the two variables is through high current levels of pollution leading to EPA inspections, rather than inspections causing immediate reductions in pollution discharge levels. These results allow us to use only lagged inspection variables without losing any of the effects of the inspections on compliance or creating a bias in our estimated coefficients.

The next variable, TONS_i, pertains to the capacity of the firm. Other things being equal, firms with larger capacity should produce more pollution, MQAVG, but need not necessarily be more likely to be in or out of compliance with EPA standards. There may be economies of scale with respect to pollution control that would tend to make large firms less likely to be out of compliance. Similarly, the TONS variable may pick up factors related to the vintage of the technology to the extent that larger plants are newer and have less polluting technologies. If these large plants are considerably more efficient in controlling pollution, the absolute levels of pollution may be lower than smaller and more outmoded facilities.

Technological factors of this type will also be captured in the SIC-code dummy variables, implying that differences in technologies and standards across parts of the pulp and paper industry will be taken into account. The regional dummy variables REGNJ also capture firm characteristics to some extent since plants in some regions tend to be older than those in other regions. These regional variables also reflect regional differences in standard setting and the nature of enforcement. These differences may be considerable due to the prominent role that the states have in the enforcement process.

The final set of variables is a series of twelve quarterly dummy variables for all but one of the quarters represented. This formulation was chosen over a simple time-trend variable because of its greater flexibility. Not only do the $\mathrm{QUARTER}_t$ variables capture any possible uniform time trend, but they also capture other quarter-specific effects such as any seasonal and cyclical fluctuations in production levels and water flows. Although some quarterly dummy variables were statistically significant, these coefficients are not reported since there was no apparent pattern evident in the results. In addition, we regressed MQAVG against both a continuous TIME variable and its square but found no significant relationships.

Regression and Maximum Likelihood Results

Table 3 reports the ordinary least squares (OLS) results for the continuous pollution measure, MQAVG, and Table 4 reports the maximum likeli-

TABLE 3

REGRESSION EQUATIONS FOR MQAVG (Quarterly Average BOD Discharge Levels in Pounds per Day)

INDEPENDENT VARIABLES	COEFFICIENTS			
	(1)*	(2)	(3)	(4)
INTERCEPT	−434.029	−460.454	−494.034	−213.905
	(1,683.935)	(1,650.046)	(1,592.309)	(1,557.062)
MQAVG4	.983	.983	.983	.982
	(.021)	(.021)	(.020)	(.020)
IQTR1	−1,174.689	−1,059.423	−1,064.031	−1,148.911
	(517.225)	(511.525)	(497.787)	(487.430)
IQTR2	575.256	381.999	398.665	...
	(495.099)	(481.687)	(469.908)	...
IQTR3	−198.047	−155.912	...	...
	(467.133)	(463.305)	...	...
IQTR4	77.479	59.709	...	...
	(468.403)	(450.159)	...	...
IQTR5	374.924	...	...	...
	(468.248)	...	...	...
IQTR6	−584.136	...	...	...
	(440.411)	...	...	...
TONS	.322	.320	.320	.329
	(.438)	(.439)	(.437)	(.437)
SIC11	414.177	382.955	410.222	310.442
	(1,408.440)	(1,408.522)	(1,394.943)	(1,389.408)
SIC21	262.356	219.433	252.081	112.177
	(1,418.355)	(1,414.941)	(1,393.285)	(1,382.926)
SIC31	−205.950	−278.427	−253.484	−365.172
	(1,426.645)	(1,424.948)	(1,410.265)	(1,403.533)
SIC48	31.976	−41.814	17.162	−241.752
	(2,806.433)	(2,789.052)	(2,719.955)	(2,701.675)
REGN1	248.482	225.870	213.567	322.009
	(909.025)	(895.892)	(862.661)	(852.791)
REGN3	−499.882	−500.628	−533.588	−360.471
	(1,864.535)	(1,823.241)	(1,764.428)	(1,751.873)
REGN4	230.897	219.572	204.147	310.894
	(890.368)	(846.406)	(807.680)	(797.493)
REGN5	59.067	107.966	115.888	147.361
	(1,298.116)	(1,299.413)	(1,295.674)	(1,294.613)
REGN6	276.987	269.784	265.636	307.939
	(625.214)	(611.374)	(597.714)	(595.387)
Adjusted R^2	.903	.903	.904	.904
N	373	373	373	373

NOTE.—Each equation also includes twelve quarterly dummy variables. Standard errors are in parentheses.

* Equation (1) uses a second-order polynomial distributed lag formulation for IQTR1–IQTR6.

TABLE 4

MAXIMUM LIKELIHOOD EQUATIONS FOR MVIO (Noncompliance with BOD Standards)

INDEPENDENT VARIABLE	COEFFICIENTS (1)	(2)	(3)	(4)
INTERCEPT	−7.872	−7.648	−7.991	−8.012
	(23.008)	(22.884)	(22.884)	(23.113)
MVIOT4	2.650	2.637	2.640	2.641
	(.362)	(.359)	(.356)	(.356)
IQTR1	−1.12	−1.019	−.920	−.914
	(.442)	(.429)	(.418)	(.413)
IQTR2	−.063	−.134	−.037	. . .
	(.421)	(.411)	(.396)	. . .
IQTR3	−.606	−.644	. . .	. . .
	(.398)	(.396)	. . .	. . .
IQTR4	−.030	−.141	. . .	. . .
	(.387)	(.369)	. . .	. . .
IQTR5	.448	. . .	. . .	. . .
	(.389)	. . .	. . .	. . .
IQTR6	.071	. . .	. . .	. . .
	(.360)	. . .	. . .	. . .
TONS	-5.07×10^{-4}	4.971×10^{-4}	-5.127×10^{-4}	-5.124×10^{-4}
	(4×10^{-4})	(3.956×10^{-4})	(3.913×10^{-4})	(3.91×10^{-4})
SIC11	6.321	6.263	6.396	6.405
	(22.998)	(22.875)	(23.108)	(23.106)
SIC21	5.800	5.754	5.958	5.968
	(22.999)	(22.876)	(23.109)	(23.107)
SIC31	5.352	5.306	5.423	5.431
	(23.00)	(22.877)	(23.110)	(23.109)
SIC48	2.506	2.404	3.064	3.084
	(23.077)	(22.951)	(23.178)	(23.175)
REGN1	1.709	1.791	1.540	1.531
	(.746)	(.736)	(.690)	(.683)
REGN3	2.188	2.474	2.033	2.015
	(1.481)	(1.412)	(1.336)	(1.319)
REGN4	1.098	1.316	1.101	1.094
	(.685)	(.655)	(.621)	(.615)
REGN5	1.835	1.868	1.951	1.950
	(.888)	(.889)	(.877)	(.876)
REGN6	−.531	−.404	−.530	−.535
	(.524)	(.505)	(.482)	(.480)
$-2(\log L)$	281.30	282.64	285.35	285.39
N	374	374	374	374

NOTE.—Each equation also includes twelve quarterly variables. Asymptotic standard errors are in parentheses.

hood estimates for the noncompliance variable, MVIO. Because of the close similarity of the findings, we discuss each of the variables in turn for both of the tables.

The four-quarter lagged pollution variable has the expected strong positive effect on the current pollution status, which suggests that past pollution levels predict current discharge levels accurately because of the slowness of the capital expenditures process needed to transform their status. Since the MVIO variable has been altered by the logistic transformation, the results for the continuous pollution measure, MQAVG, can be interpreted more readily. It is quite striking that the weight placed on the four-quarter lagged pollution value is in excess of 0.98 in each of the four equations. Thus, there is almost complete replication of the pollution experience across time. All else being equal (in particular, controlling for inspections), past pollution performance is close to a perfect predictor of current pollution levels.

The next set of variables pertains to the set of lagged inspection variables. Consider the continuous discharge measurements in Table 3. In equation (1) there is a second-order polynomial distributed lag over inspection variables for the preceding six quarters, equation (2) is a free-form lag over four quarters, equation (3) is a free-form lag over two quarters, and equation (4) includes only a single lagged value. The pattern is strikingly similar in all four equations. There is a consistently significant and substantial influence of IQTR on reducing discharge levels that occurs with a one-quarter lag. Lagged values of more than a quarter are not consequential. The discrete compliance status equations in Table 4 convey the same influence of inspections; that is, they cause significant reductions in the rate of noncompliance in the subsequent quarter.[27]

The magnitude of the inspection effect is substantial. Consider equation (4) in Table 3. Each inspection reduces the value of MQAVG by 1,149 pounds per day, which represents about a 20 percent reduction in the mean value of BOD discharges.[28] Since the coefficients of subsequent IQTR variables are never significantly positive, there is no evidence of a

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[27] Our results suggest that inspections tend to induce reduced discharge levels and enhanced compliance through immediate attention to better plant operation and maintenance, rather than longer-term capital investments. This finding is consistent with the observation in Wasserman, *supra* note 10, that the EPA's main enforcement problems in the water pollution area involve failure to operate and maintain treatment systems already in place rather than investment in new treatment systems.

[28] A paper by Jonathan S. Feinstein (Detection-controlled Inference (working paper, M.I.T., Dep't of Econ., 1986) provides an econometric argument for why the coefficients of the inspection variables would be biased downward if detection of noncompliance were masked by the nonsubmittal of DMR data. Thus, our results about the effect of inspections provide a lower bound on their true magnitude.

significant postinspection rebound in pollution discharge levels. These results imply that a permanent improvement in discharge levels takes place as a consequence of the inspection and all associated enforcement actions. Further, the 1,149 pounds per day reduction in BOD in period *t* is reflected in an approximately equal reduction four quarters hence because the coefficient of MQAVG4 is 0.982. Thus, inspections substantially reduce BOD discharges after about one quarter, and they have a permanent effect on reducing the firm's future pollution levels.[29]

The compliance status results from Table 4 also indicate a large effect of the inspections, and their associated enforcement actions, on noncompliance rates. The coefficients of IQTR1 in equations (1)–(4) average −1.0, implying that had the source not been inspected its odds of being in noncompliance would have been about double. Since most plants in the sample were inspected about once a year and the average rate of noncompliance is 25 percent, the coefficients from the table suggest that without an inspection this noncompliance rate would have been 48 percent.

Finally, the TONS measure has the expected sign in each case, as firms with larger capacity have higher total levels of pollution and lower chances of being out of compliance. Neither effect is statistically significant, however. Similarly, the SIC and regional dummy variables fail to yield any statistically significant effects.

One might expect that the magnitude of the inspection effect would vary with the firm's present noncompliance status. To test this hypothesis, Table 5 presents the key coefficients for equations (3) and (4) from Table 3 in which the inspection variables have been interacted with the compliance status at the time of the inspection. In particular, IPVIO1 equals one in a quarter when a source was inspected one quarter earlier *and* had a permit violation when it was inspected; otherwise it equals zero. IPNOVIO1 equals one in a quarter when a source was inspected one quarter earlier and did not have a permit violation during the quarter of the inspection, and zero otherwise. Similar definitions apply to IPVIO2 and IPNOVIO2, except that these variables have a two-quarter lag.

The results in Table 5 indicate effects of inspections with a one-quarter lag, but no significant effects with a two-quarter lag. Both the IPVIO1 variable (1 percent confidence level, one-tailed test) and the IPNOVIO1 variable (5 percent confidence level, one-tailed test) are statistically sig-

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[29] When the inspection variables were redefined to separate the effects of compliance sampling inspections from the effects of compliance evaluation inspections (without sampling), we found no significant differences between the effects of the two types of inspections. While care must be taken in interpreting this result because the sample size is relatively low, it suggests that sampling inspections may not be worth their added costs.

TABLE 5

COMPARISON OF EFFECTIVENESS IN REDUCING DISCHARGE LEVELS (MQAVG) OF INSPECTIONS ON SOURCES OUT OF COMPLIANCE VERSUS SOURCES IN COMPLIANCE

	COEFFICIENTS	
VARIABLE*	Equation (1)	Equation (2)
IPVIO1	−1,436.733	−1,606.712
	(861.402)	(850.242)
IPNOVIO1	−766.114	−922.998
	(572.448)	(560.809)
IPVIO2	676.362	...
	(810.234)	...
IPNOVIO2	712.996	...
	(567.250)	...

NOTE.—Standard errors are in parentheses.

* For ease of exposition, the coefficients of all the other variables in the equation are not recorded. These variables are identical to those in Table 3.

nificant, so that the inspections reduce pollution levels irrespective of the compliance status.

The point estimates are consistent with one's expectations concerning the relative magnitude of the effects, as the reductions achieved for firms out of compliance are almost double those that are produced for firms not in violation of their permit. For example, from equation (2) we have the result that a source out of compliance was associated with a 684 (= 1,607 − 923) pound per day greater decrease in BOD discharge levels than a source in compliance. It should be noted, however, that the standard errors of the coefficients imply that the 95 percent confidence intervals for the IPVIO1 coefficient and the IPNOVIO1 coefficient overlap, so that this result should be treated with appropriate caution.

Effects on the Incidence of DMR Nonreporting

While our econometric results in the beginning of this section clearly point to the conclusion that plant inspections cause firms to both reduce their pollutant discharge levels and come more closely into compliance with their discharge permits, inspections do serve other purposes as well. One of these is to induce firms to report more regularly their discharge levels to the EPA or the designated state enforcement agency. We now examine whether inspections tended to reduce the incidence of DMR

TABLE 6

Mean Difference between the Number of DMR Reports before an Inspection and the Number of DMR Reports after an Inspection

Number of Months of Possible DMR Data prior to and after Inspection	Mean Difference Averaged across All Inspections in Period
1. Four months:	
a. May 1977–November 1984	−.386 (.060)
b. May 1982–November 1984	−.425 (.108)
2. Six months:	
a. July 1977–September 1984	−.714 (.090)
b. July 1982–September 1984	−.868 (.173)
3. Twelve months:	
a. January 1978–March 1984	−2.107 (.196)
b. January 1983–March 1984	−1.693 (.477)

Note.—Standard errors of the mean are in parentheses.

nonreporting as measured by the fraction of months without DMR entries in the PCS data base.[30]

Table 6 suggests that there is such a reporting effect for the firms in our sample. The first line in the table measures the difference between the number of months that DMR data was submitted in the four months prior to an inspection and the number of months with DMR data in the four months immediately following the inspection, averaged across all inspections in one of two periods, May 1977–November 1984 and May 1982–November 1984. The second line reports the analogous differences for a six-month period before and after the inspections, while the third line provides results for a twelve-month period of DMR data. All six mean differences are negative and more than two standard errors away from zero, indicating high levels of statistical significance. Thus, the completeness of DMR reporting is clearly higher after inspections.

We must add one note of caution in interpreting these statistics because the mean differences are not adjusted for the trend of increased reporting of DMR data. Still, this trend could not explain much of this difference.

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[30] As the discussion in Section III explained, missing DMR data can result either from the failure of firms to report the data to EPA regions or the states or from the failure of the regions or states to enter the reports in the PCS data base. While the first type of failure is probably more closely related to noncompliance than the second type, both reasons for missing PCS data on the DMRs make the PCS system less useful for monitoring enforcement.

To be conservative, consider the first line of the table reporting four months of DMR data, where the trend ought to be least important. For both the long and short periods, the mean difference averages about −0.10 reports per month, which implies that inspections cause one additional month of DMR data to be reported out of every ten months. If the underlying trend of increased reporting accounted for, say, half of this difference (that is, −0.05), then less than twenty months would have to pass before *no more* nonreporting of DMR data would occur. Since the period from May 1977 to November 1984 (line a) contains eighty-four months, the underlying trend must be negligible relative to the rates of increased reporting of DMR data implied by the mean differences in Table 5.

Thus, inspections did tend to cause increased reporting of DMR data into the PCS data base by the firms in our sample, which in turn allows the EPA to more accurately monitor, and therefore enforce, its water pollution standards.

V. EXPLORATORY BENEFIT-COST ANALYSES

One might conclude that EPA inspections are successful because all three of our measures of firms' responses to inspections show significant effects. From a social welfare perspective, however, this question requires valuing the benefits of the effluent reductions induced by an inspection and comparing these benefits to the full costs of each inspection. In what follows, we provide a preliminary exploration of the components of such a benefit-cost analysis. Unfortunately, the existing estimates of the benefits per ton of BOD eliminated per year are only approximate, and we could find no estimates of the compliance costs due to an inspection. As a result, this exercise is highly imprecise. Nevertheless, it does provide some perspective on the welfare consequences of the EPA inspection program for industrial water pollution.

Vaughan and Russell[31] have estimated the national benefits from the improvements in freshwater quality due to the BPT standards at $683 million (in 1980 dollars). While this estimate includes both the out-of-pocket expenses and the opportunity costs of the time of fishermen, it does not include the aesthetic benefits of fishing on cleaner waters, or other benefits such as those from swimming and boating. Development Planning and Resource Associates[32] estimated that the BPT standards

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[31] William J. Vaughan & Clifford S. Russell, Freshwater Recreational Fishing: The National Benefits of Water Pollution Control 161 (1982).

[32] Development Planning and Resource Associates, Inc., National Benefits of Achieving the 1977, 1983, and 1985 Water Quality Goals (1976).

would reduce BOD discharges by 3,390,233 tons per year, which together with the previous estimate implies an average value of benefits per ton of BOD removed due to the BPT standards of $201.46.

Using equation (4) in Table 3, each inspection will tend to cause a reduction in BOD discharges of 1,148 pounds per day, or 209.51 tons per year. Given the previous benefits estimate of $201.46 per ton, this implies that an average inspection produces $42,208 of benefits every year.[33]

Given the 0.982 coefficient of the MQAVG variable lagged four quarters in equation (4) in Table 3, the effectiveness of an inspection in maintaining lower effluent discharge levels decays at a negligible rate. Accepting the linear form of the equation and rounding this coefficient to 1.0, the equation implies that any BOD reductions from an inspection remain in force for years after the inspection. Thus, we can approximate the annualized benefits per inspection at $42,208.

Given the mix of inspections in our sample of 43 percent compliance sampling inspections (requiring approximately thirty days) and 57 percent compliance evaluation inspections (requiring approximately three days), an average inspection required 14.6 days. Assuming the full cost of inspectors to be $50,000 per year over 220 working days yields a cost of $227 per day, or $3,315 per inspection. Figuring this inspection cost at a 10 percent discount rate gives an annual cost of $332.[34] Calculating the net inspection cost from the benefits gives an adjusted annualized benefit of $41,876 per inspection.

Consider now whether the average annual compliance costs incurred due to inspections are likely to exceed $41,876 per inspection. Since 75 percent of the firms sampled were already in compliance, we would expect them to spend little or nothing after an inspection. Thus, each noncomplying firm must spend at least four times $41,876, or $167,504, per year in order that the costs associated with an inspection exceed their benefits.

Whether compliance costs exceed this threshold probably hinges on whether the firm must make a capital investment to attain compliance or whether a change in operating procedures will suffice. Although detailed

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[33] This calculation assumes that the average benefits of each pound of BOD removed due to an inspection equal the nationwide average benefits of the BPT standards. This simplifying assumption ignores the fact that the effluent reductions at some plants induced by inspections will yield benefits much greater than the average, whereas inspections at other plants, even if they result in lower emissions, will improve water quality much less than for an average inspection. Without more disaggregated information about benefits, we were forced to make this simplifying assumption.

[34] The use of a 10 percent discount rate is required by the Office of Management and Budget, but other more realistic rates would not significantly affect our conclusions.

cost data are not available for all portions of the pulp and paper industry, some suggestive statistics are available for the costs of an activated sludge treatment system used to comply with the BPT standards in the wastepaper-molded products subcategory of the industry.[35]

For a concrete example, focus on the intermediate-size plant (45 kg/day). Compliance for these firms entails an annual operation and maintenance outlay of $113,000, annual energy cost of $19,000, and an average annual capital cost of $339,000, leading to a total annual cost of $471,000.[36] If compliance following an inspection involves only the operation and maintenance costs, the expenditure of $132,000 is somewhat below the value of benefits less inspection costs. However, if a capital investment is required, the costs exceed the pollution reduction benefits net of enforcement costs by a factor of almost three.

For small plants, with a total annual compliance cost (including amortized capital costs) of $288,000, the compliance costs outweigh benefits once capital costs are included. For large wastepaper-molded products plants with average annual compliance costs of $879,000, even the operation and maintenance costs of $176,000 exceed the pollution reduction benefits.[37]

To the extent that the rough estimates in this particular case reflect the costs and the benefits for other industry subcategories, the following conclusion holds. If inspections lead firms to make substantial capital investments, then the costs of compliance exceed the benefits. Once having made these investments, firms may be more likely to undertake the appropriate operating procedures to maintain their compliance status as a result of an inspection. This promotion of continued vigilance on the part of firms that have already made the required capital investment is more likely to pass a benefit-cost test.

VI. CONCLUSION

Compared with other health, safety, and environmental regulations, EPA water pollution regulations for the pulp and paper industry represent an unusual success story. The EPA sets standards for which compliance

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[35] While wastepaper-molded product is only one of many subcategories in the industry, the activated sludge treatment system represents a standard technology for biological treatment of pulp and paper mill wastes.

[36] All the cost estimates are found in U.S. Environmental Protection Agency, Development Document for Effluent Guidelines and Standards for the Pulp, Paper, and Paperboard and the Builders' Paper and Board Mills (1982).

[37] See U.S. EPA, *supra* note 36.

is feasible and then enforces these standards relatively vigorously, with inspections averaging one per year for our sample. This mix is the opposite of OSHA's, which has stringent standards coupled with weak enforcement. The coupling of regulations for which compliance is feasible with stringent enforcement is likely to create strong incentives for compliance, and the available evidence bears this out. Inspections and their associated enforcement actions have a strong effect on both pollution levels and rates of compliance with the permit levels. In addition, inspections are associated with less nonreporting of pollutant discharge levels. Judged with respect to its legislative mandate to improve water quality, this effort is clearly a success.

In view of the evident effectiveness of the water pollution enforcement effort, one might well ask whether U.S. water quality should not have improved overall as a result of such efforts. This may not be a meaningful test, however, since the real issue is whether water quality would have been worse in the absence of EPA enforcement, not whether the overall level of water quality has improved. With economic growth, the baseline rate of total discharge of BOD should be increasing. Coupled with a fixed assimilative capacity of any body of water, this growth implies that there should be deteriorating water quality in the absence of EPA actions.

Available information on national surface water quality trends shows modest improvements in the late 1970s and early 1980s. The Council on Environmental Quality reported in their fifteenth annual report that "significant progress has been achieved in cleaning up the nation's waters."[38] This conclusion is based on an assessment by the Association of State and Interstate Water Pollution Control Administrators (ASIWPCA) of the degree to which beneficial uses were supported in surface waters assessed in each state. The ASIWPCA reported that in 1982 64 percent of assessed surface waters supported their designated uses, compared with 36 percent of 1972.[39] In their 1986 Report to Congress, the EPA reported that 74 percent of assessed river miles fully supported their designated uses.[40]

These results are consistent with the conclusions of the ASIWPCA and the EPA in their report, *The States' Evaluation of Progress, 1972–1982.* Based on an evaluation of 42 percent of the nation's streams, they re-

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[38] Council on Environmental Quality, Environmental Quality: 15th Annual Report 85 (1984).

[39] Council on Environmental Quality, Environmental Quality: 17th Annual Report C-42 (1986).

[40] U.S. Environmental Protection Agency, National Water Quality Inventory: 1986 Report to Congress 2 (1986).

ported that, between 1972 and 1982, 47,000 miles of assessed streams improved in quality while 11,000 miles declined.[41]

Available data are insufficient to assess changes in ambient BOD levels of an annual or regional basis; however, the Council on Environmental Quality reported that BOD discharges from pulp and paper mills decreased from 706.8 thousand tons in 1974 to 207.6 thousand tons in 1984.[42]

One might raise the more general issue not treated by the EPA's enabling legislation: whether the benefits accruing from this pollution reduction are commensurate with their costs. This calculation needs substantially better data to refine it, but some preliminary observations are in order. If one includes only the operation and maintenance cost associated with pollution control, then the benefits of inspections may exceed their costs. If capital costs are included as well, the results are probably reversed. One major difficulty associated with this calculation is that we cannot distinguish which incremental pollution control expenditures are associated with the effect of the inspections. Notwithstanding these caveats, it appears that the EPA water pollution regulations represent a dramatic departure from the apparent impotence of most other forms of health, safety, and environmental regulation. The remaining challenge is to set standards at a level that will ensure that the regulations are in society's best interests.

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[41] Council on Environmental Quality, *supra* note 38, at 82–83.

[42] Council on Environmental Quality, *supra* note 39, at C-38.