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Compliance and Enforcement: Air Pollution Regulation in the U.S. Steel Industry[1]

WAYNE B. GRAY

Department of Economics, Clark University, Worcester, Massachusetts 01610

AND

MARY E. DEILY

Department of Economics, Lehigh University, Bethlehem, Pennsylvania 18015

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We use data on individual steel plants to study the relationship between regulators' enforcement of air pollution regulations and firms' compliance decisions. We find the expected interactions between the decisions: at the plant level, greater enforcement leads to greater compliance, while greater compliance leads to less enforcement. We also test whether differences in firms' characteristics affect either compliance or enforcement decisions at the plant level, holding plant characteristics constant, and find that they seem to matter more for enforcement than for compliance.

1. INTRODUCTION

Enacting pollution-control legislation is only the first step toward less pollution: continued monitoring and enforcement is necessary to ensure that firms invest in the appropriate control technology and that they operate it properly (Russell [17]). However, little research exists on the actual regulatory experience: that is, how enforcement encourages compliance and how compliance behavior influences enforcement allocation. In this paper we use data on the steelmaking plants operated by integrated steel firms during the years 1980–1989 to study the links, at those plants, between enforcement of air pollution regulations and firms' compliance decisions.

Previous work on compliance and enforcement behavior utilizes industry-level data or is focused on one of the two decisions. Magat and Viscusi [15], examining pulp and paper mills' compliance with water pollution regulations, found that inspections increase future compliance. Bartel and Thomas [2] estimated a three-equation model of compliance, injury rates, and OSHA enforcement decisions, and found that, across industries, the probability of inspection increases average industry compliance, but that average compliance rates have no significant affect

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on inspection rates. However, both Carson [3] and Fenn and Veljanovski [9], using establishment-level enforcement data on British health and safety inspections, found that regulators were likely to use more severe enforcement measures when they felt that management was uncooperative.

Here we use data on enforcement and compliance decisions at the plant level to investigate whether regulators' decisions influenced firms' compliance behavior, and in turn whether a firm's compliance decisions affected enforcement pressure directed toward its plants. Because many plants in our sample closed when the steel industry contracted during the 1980s, however, we must also consider the possibility that compliance and enforcement behavior were entwined with plant-closing decisions, as found in Deily and Gray [7]. Thus, our model has three equations: a compliance decision made by the plant's owning firm, a plant-closing decision also made by the firm, and an enforcement decision made by regulators (both federal and state).

Enforcement and plant-closing decisions may be linked if a regulator allocating enforcement effort in a declining industry is sensitive to the possibility that certain plants would close rather than comply, or if firms estimate future enforcement pressure when evaluating a plant's long-run expected profit. Enforcement and compliance decisions may be linked if regulators reduce enforcement pressure at plants currently in compliance, or if firms are more likely to comply at plants facing greater enforcement pressure, or at those with a greater chance of surviving the decline.

In addition to studying these linkages, a second goal of the paper is to investigate whether and why a firm's characteristics might affect compliance or enforcement decisions at a plant. For instance, economies of scale in compliance could make large, multi-plant firms more likely to comply with regulations; or, firms may place different values on their reputation in the community, leading to differences in compliance behavior. Because we have information about both the firms that own each steel plant and the individual plants, we can test whether firm characteristics have any impact on either compliance or enforcement behavior after we have controlled for plant-level variation.

We use the integrated steel industry in our study for three reasons. First, its decline allows us to check for regulators' sensitivity to plants under extreme financial pressure. Second, we can examine the interplay between enforcement and compliance decisions at the plant level because we were able to develop data for such variables as compliance costs for individual steel plants. Third, the wide variation among steel firms in profitability, diversification, and overall corporate size, allows us to test whether these or other firm-level variables affect either enforcement or compliance decisions at the plant level.

We outline the model and specification for each equation in Section II. In Section III, we go over data and econometric issues. We review the results in Section IV, and Section V is the conclusion.

II. MODEL AND SPECIFICATIONS

We estimate the relationships between three potentially endogenous decisions, enforcement, compliance, and plant closing, in two stages. In the first stage, we generate predicted versions of each decision by regressing actual experience on a set of instruments. The resulting predictions for enforcement and compliance at each plant each year, as well as the estimated probability of each plant's being closed during the industry contraction, are used in the structural specifications discussed below.

The Compliance Decision

In our model a compliance decision is made for each plant each period; while initial compliance may involve investment in equipment, continuing compliance involves operation of that equipment and any additional procedures or investments that may be warranted. The simplest version of this decision has compliance determined solely by plant characteristics:

$$\mathrm{COMP}_{i,t} = f(\mathrm{PLTACT}_{i,t}, \mathrm{CCOST}_i, \mathrm{PCLOSE}_i, \mathrm{LPCAP}_i), \tag{1}$$

where i indexes plants, and t indexes time. We use qualitative data on whether a plant was in or out of compliance for the dependent variable, COMP, a dummy which equals 1 if the plant is in compliance in year t, and zero if it is not.

We assume that a firm weighs the cost of compliance against the expected penalty for noncompliance in making its decision. The expected penalty depends on how frequently the plant is inspected and on the resulting fine if a violation is found. We do not have data on fines, but we do have data on the enforcement actions directed toward each plant each year, including inspections, letters, phone calls, and enforcement orders. The variable PLTACT measures expected enforcement pressure as the predicted (i.e., estimated in the first stage) log of the total number of these actions. We also try a more restrictive measure, PLINSP, which counts inspections only, because other types of actions may arise automatically from past non-compliance, or may simply be regarded as less important by firms. As another alternative, we try dummy variables measuring lagged actual enforcement.[2] DTACT equals one if the plant experienced any enforcement actions in the prior 2 years; DINSP is a similar measure for inspections. As enforcement pressure imposes additional costs on non-complying plants, the coefficients of any of these enforcement measures should be positive.

We model the costs of compliance with three variables. First, a firm must consider the expenditure required to bring a plant into full compliance and keep it there. The variable CCOST measures the total capital cost of bringing a plant into compliance, based on the different types and mixes of equipment within each plant. (Details are available from the authors.) Since a firm is less likely to bring a plant into compliance as the cost of doing so increases, the coefficient of CCOST should be negative.

Second, in a situation of industry decline compliance costs will vary across plants with expected plant lifetime: the fixed cost of compliance, measured in dollars per ton of steel shipped, will be higher for a plant soon to close. The variable PCLOSE,

[2] Lagging the enforcement measure reduces possible endogeneity concerns that arise from using current enforcement. Also, it allows time for enforcement to have an impact: Gray and Scholz [13], studying OSHA enforcement, find that inspections reduce injuries for up to 3 years. We also tested a continuous enforcement measure (the number of past actions), but dummy measures perform better because additional actions after the first one have little impact (Gray and Scholz [13] find a similar advantage from using dummy measures of OSHA enforcement).

the probability that plant i will close during the industry's decline, is generated in the first stage of estimation. Since a firm is less likely to spend money on a plant it plans to close, the coefficient of this variable should be negative.

Third, if there are scale economies in air pollution control technology,[3] compliance at larger plants may be more likely because of the lower cost per unit of reducing emissions. The variable LPCAP is the log of a plant's steelmaking capacity in the late 1970s. If economies of scale in compliance exist, then larger plants may be more likely to be in compliance, and the coefficient will be positive.

Next we consider avenues through which the nature of its owning-firm might affect compliance at a plant. We start by considering how a firm's characteristics might affect the cost of compliance at the plant. First, economies of scale in compliance at the firm level would lower the per ton cost of complying for larger steel firms. Such economies might arise, for example, if there are fixed costs to learning about the regulations, or in researching their implementation. The variable LFCAP is the total steel capacity of the firm each year; if larger firms find compliance relatively cheaper, ceteris paribus, then the coefficient should be positive.

Second, recent work on how liquidity constraints affect investment has revived an older hypothesis that capital is cheaper for firms that can ‘‘borrow’’ internally.[4] If firms with greater cash flows have lower capital costs, they will find it cheaper to invest in pollution control equipment than firms forced to borrow external funds. The variable STEEL, the percentage of a firm's work force employed in the steel division, is a measure of the firm's lack of diversification. Undiversified steel firms might find compliance more costly than diversified firms if the latter, with access to cash flows from industries unaffected by decline, are able to use cheaper internal financing. If firms specializing in steel find financing compliance more costly, then the coefficient of STEEL will be negative. We also include the variable CASH, the gross rate of return earned by the firm. If CASH is a good measure of internal cash resources, and if liquidity constraints raise the cost of compliance, then the coefficient of this variable will be positive.

Third, Carson [3], Fenn and Veljanovski [9], and Bardach and Kagan [1] found that inspectors' enforcement decisions were affected by their perceptions of how cooperative an establishment's management was. While a reputation for cooperation may be associated mainly with a plant's managers, it is possible that a firm might develop a cooperative reputation that could affect regulators' attitudes toward others of its plants. If so, a multi-plant firm might be more willing to comply at a plant, ceteris paribus, since compliance at any single plant would create a positive externality for its other plants by adding to the firm's good reputation.

The variable SINGLE is a dummy that equals one if a firm owns only one steel plant, and zero if the firm owns multiple (steel) plants. If some part of expenditures on compliance accrues to the firm as a good reputation, and if that reputation affects enforcement decisions at its other plants, then firms with more than one

[3] The FTC [8] cites estimates by A. D. Little suggesting significant economies of scale in controlling air pollution by steel production.

[4] See Chirinko [4], pp. 1902–1903, for a review of the literature.

plant may be more likely to invest in compliance. We thus expect the coefficient of SINGLE to be negative.[5]

Aside from cost considerations, some firms may have corporate cultures that incline them toward compliance with the law, while others may have the opposite, renegade, attitude.[6] The variable FCOMPL is the compliance rate at a firm's other plants in the previous year.[7] If a corporate "attitude" (either positive or negative) toward compliance exists, then we would expect that a firm that has recently been in compliance at its other plants is more likely, ceteris paribus, to bring this plant into compliance as well, and so the coefficient should be positive. We try two other versions of this variable: HFCOMP, which is the average of all previous (available) years of compliance rates at the firm's other plants, and AFCOMP, which is the firm's average compliance rate at other plants during all other years of the sample period, both past and future. Again, the coefficients of these variables should be positive.

Finally, we add year dummies to control for annual changes in compliance behavior driven by common shocks to the industry or by changes over time in the rules defining compliance. The variables of the compliance equation are summarized in Table I.

The Enforcement Decision

We model regulators as allocating enforcement to maximize net political support (Stigler [19]; Peltzman [16]). The simplest version of the model has enforcement decisions determined by plant-level considerations:

$$\text{LTACT}_{i,t} = f(\text{PCOMP}_{i,t}, \text{LEMIT}_{i,t}, \text{ATTAIN}_i, \text{CCOST}_i, \text{PCLOSE}_i, \text{LRELEMP}_{i,t}, \text{CNTYU}_{i,t}), \quad (2)$$

where i indexes plants, and t indexes time. The dependent variable, LTACT, is the log of the total enforcement actions faced by a plant during the year. We also use the alternative measure, LINSP, which is the log of the number of inspections experienced by a plant during the year.

Enforcement activity increases political support by pleasing the general public, which we assume would prefer to have lower levels of pollution at the least cost. Thus, we expect regulators to direct more enforcement toward plants they expect to be out of compliance, because doing otherwise would be wasteful, and because various theoretical models have shown that regulators may increase overall industry compliance by targeting establishments that are persistent violators (Scholz [18];

[5]Some single-plant firms, particularly those created when larger steel firms sold off individual plants, were privately held, so that data on firm-level employment and gross rate of return were not available. In these cases, we used various approximations (described in the data appendix) to impute values for the missing observations. Thus, the SINGLE dummy may reflect the effects of imputed firm-level data as well as true differences between single and multi-plant firms.

[6]The definition of a renegade or "bad apple" varies among authors. The basic idea seems to be that the corporate culture of such a firm includes no automatic distaste for or disutility from incurring law suits, breaking the law, or hurting the community (Bardach and Kagan [1]; Clinard and Yeager [5]; Stone [20]).

[7]We set FCOMPL equal to zero if a firm owns no other plants. This should not bias the FCOMPL coefficient because the variable SINGLE captures the average compliance behavior of single-plant firms.

TABLE I

Variable Definitions, Means, Standard Deviations, and Expected Signs

	Mean	S.D.	Sign
Compliance equation			
Dependent variable			
COMP: 1 if plant in compliance in year t; 0 if not	0.38	0.49	—
Plant characteristics			
PLTACT: predicted log of (1 + total enforcement actions), for plant i in year t	2.20	0.84	+
DTACT: 1 if plant i experienced an enforcement action in past 2 years; 0 otherwise	0.96	0.20	+
PLINSP: predicted log of (1 + number of inspections), for plant i in year t	1.26	0.63	+
DINSP: 1 if plant i experienced an inspection in past 2 years; 0 otherwise	0.91	0.28	+
CCOST: dollars per ton of capacity to bring plant i into full compliance	26.37	8.74	−
PCLOSE: predicted probability that plant will close during industry contraction	0.25	0.31	−
LPCAP: log of plant i capacity, in millions of annual tons	1.07	0.56	+
Firm characteristics			
LFCAP: log of firm's total steel capacity, in millions of annual tons, in year t	4.20	1.16	+
STEEL: percentage of firm's work force employed in its steel division in year t	45.73	23.24	−
CASH: firm's gross rate of return in year t	0.02	0.07	+
SINGLE: 1 if firm owns single steel plant in year t; 0 otherwise	0.23	0.42	−
FCOMPL: average compliance rate at firm's other plants in previous year; 0 if firm has no other plants	0.22	0.30	+
HFCOMP: average compliance rate over all past years at firm's other plants; 0 if firm has no other plants	0.15	0.19	+
AFCOMP: firm's average compliance rate at its other plants in all other years; 0 if firm has no other plants	0.21	0.21	+
Enforcement equation			
Dependent variables			
LTACT: log of 1 + all regulatory actions directed toward plant i in year t	2.24	1.16	—
LINSP: log of 1 + inspections directed toward plant i in year t	1.35	0.93	—
Plant characteristics			
PCOMP: predicted compliance by plant i in year t	0.38	0.24	−
COMPL: 1 if plant in compliance in year $t - 1$; 0 otherwise	0.36	0.48	−
LEMIT: log of tons of emissions produced by plant i in year t	8.78	1.26	+
ATTAIN: attainment status of plant i's county	0.18	0.39	−
CCOST: dollars per ton of capacity to bring plant i into full compliance	26.37	8.74	−
PCLOSE: probability that plant will close during industy contraction	0.25	0.31	−
LRELEMP: log of percentage of county labor force employed at plant i in year t	0.74	1.62	−
CNTYU: unemployment rate in plant i's county in year t	9.57	3.74	−
LSTTACT: log of total enforcement actions in plant i's state in year t	7.52	0.75	+
LSTINSP: log of number of inspections in plant i's state in year t	6.89	0.86	+

TABLE I—*Continued*

	Mean	S.D.	Sign
Firm characteristics			
LEMPLOY: log of firm's total employment (in thousands) in year t	3.69	1.27	−
STEEL: percentage of firm's work force in its steel division in year t	45.73	23.24	−
CASH: firm's gross rate of return in year t	0.02	0.07	+
FCOMPL: average compliance rate at firm's other plants in previous year; 0 if firm has no other plants	0.22	0.30	−
HFCOMP: average compliance rate over all past years at firm's other plants; 0 if firm has no other plants	0.15	0.19	−
AFCOMP: firm's average compliance rate at its other plants in all other years; 0 if firm has no other plants	0.21	0.21	−
SINGLE: 1 if firms own single steel plant in year t; 0 otherwise	0.23	0.42	?

Harrington [14]).[8] If inspections at plants that are persistent offenders increases the likelihood of compliance at other plants, then regulators are more likely to inspect persistent offenders, ceteris paribus.

The variable PCOMP is the probability of compliance at plant i in year t generated from the first-stage estimations. Since we expect less enforcement at a plant likely to be in compliance, the coefficient of this variable should be negative. However, instead of its current characteristics, regulators may use a plant's recent past to signal the likelihood of its current compliance. As an alternative to PCOMP, we test the variable COMPL, plant i's actual compliance status in the previous period, lagged to reduce endogeneity concerns and expected to have a negative coefficient. Since some non-inspection enforcement actions may be automatically generated by non-compliance (e.g., phone calls or enforcement orders), we might expect to see a greater impact of compliance, or of lagged compliance, on total actions.[9]

We think the public may also be more sensitive to plants emitting large absolute amounts of pollution, and thus that regulators may inspect such plants more frequently, even if the plant is in compliance. The variable LEMIT is the log of emissions produced by plant i in year t; if regulators focus on large sources of emissions, then the coefficient of LEMIT will be positive. However, the public's desire for cleaner air may vary from place to place, depending on local conditions; in fact, federal regulations require stricter controls for plants in non-attainment areas. The variable ATTAIN is a dummy that equals one if the plant is located in an attainment area, and zero otherwise. We expect the coefficient of ATTAIN to be negative, as we expect more effort to reduce pollution in more heavily polluted areas.

[8] Scholz conveys the flavor of this argument by reporting that, according to Chester Bowles, "...about 20 percent of all firms will comply unconditionally with any rule, about 5 percent are always going to disobey, and about 75 percent are also likely to comply but only if the threat of punishing the incorrigible 5 percent is convincing..." (Scholz [18], p. 184).

[9] We thank a referee for this suggestion.

We predict less enforcement activity will be directed toward steel plants that firms most strongly resist bringing into compliance, since inducing compliance has a higher expected cost in agency resources and in possible loss of political support. Given a set schedule of fines, a firm has more incentive to resist enforcement efforts the greater is the cost of bringing a plant into compliance.[10] In the limit, where either the fines or the costs of compliance reduce the value of the plant to zero, the firm would shut down the plant rather than comply, a possibility regulators may be particularly aware of when dealing with plants in a declining industry. We thus expect the variable CCOST, the cost of brining a plant into compliance, and the variable PCLOSE, the probability that the plant will close, to have negative coefficients.

Another source of opposition to agency activity is employees and other local citizens threatened by a plant closing. The political costs of even appearing to cause a plant to shut down may induce regulators to direct enforcement toward plants for which the probability of closing, and the adjustment cost if closing occurs, are lower. Aside from the purely political considerations, it may be more efficient to avoid spending agency resources on a marginal plant, since time is likely to take care of the problem. The variable LRELEMP is the log of the ratio of employment at the plant to employment in the local labor market; and CNTYU is the local area unemployment rate. We expect the coefficients of both these variables to be negative, since pressuring plants whose closing would be very damaging to the local community could have high political costs for the agency.

Even after controlling the above sources of plant-level variation, a firm's characteristics may still affect enforcement decisions aimed at individual plants. First, regulators may be less likely to pressure plants owned by a firm with more political power, since such firms are more capable of reducing political support for the agency. We use firm size as a measure of political power, and expect the coefficient of LEMPLOY, the log of a firm's total employment, to be negative.

Next, regulators may exert more pressure against plants owned by firms they feel can better afford compliance; expecting less resistance in such cases, regulators may anticipate a greater payoff for their efforts. We use a firm's specialization in the steel industry, STEEL, as a readily available measure of ability to pay that regulators might plausibly take into consideration, particularly in a situation of industry decline. If regulators feel that firms with access to non-steel revenues find compliance more affordable, then the coefficient of this variable will be negative. Another, perhaps less plausible, measure of ability to pay that regulators may be aware of is profitability. We try the variable CASH, a firm's gross rate of return: if regulators direct more enforcement pressure toward plants owned by more profitable firms then the coefficient will be positive.

Finally, a firm with plants persistently out of compliance may develop a reputation for recalcitrance, and find that all its plants receive more attention from regulators as a result. We include the variable FCOMPL, a firm's compliance rate in the previous year at its other plants, to capture the effect of a firm's compliance behavior elsewhere on enforcement at plant i. If regulators respond to compliant

[10] Firms may face higher costs from extra investment, from increased operating costs, and/or from reduced productivity when they bring a plant into full compliance (Crandall [6]; Gollop and Roberts [10]). See Gray ([11], [12]) for evidence that industries facing heavy enforcement tended to have lower productivity growth.

behavior on the firm's part by reducing enforcement efforts toward its plants, then the coefficient of this variable will be negative. We try two other formulations, HFCOMP (the firm's historical compliance rate at other plants), and AFCOMP (the firm's compliance rate at other plants over the whole period), as alternative gauges of the firm's compliance reputation, and the coefficients of these measures should also be negative. Since each of these reputation variables is zero for firms that own just one steel plant, we include the single-plant dummy SINGLE, as well.

We try two methods for controlling variation in the general level of enforcement across states. For one we use a limited set of state dummies, one for each state with more than one steel plant.[11] For the other we replace the state dummies with the variable LSTTACT, the log of the number of enforcement actions directed toward all other regulated plants in that state each year. (The variable LSTINSP, log of the number of inspections, is used when the dependent variable is LINSP.) In all cases we include year dummies to control for variation in the general level of enforcement over time. These variables are summarized in Table I.

The Plant-Closing Decision

In Deily and Gray [7], we used two-stage estimation to explore the relationships between plant closing and enforcement decisions. We found that PCLOSE, the plant-closing probability generated for each plant in the first-stage estimation, did influence enforcement decisions. Here we reuse the probabilities estimated for PCLOSE in our previous paper and expect them to influence both enforcement and compliance decisions as discussed above.[12]

III. DATA AND ECONOMETRIC ISSUES

Our sample consists of 41 steelmaking plants in the United States that were open in 1980; they represent virtually all capacity operated by integrated steel firms. EPA's Compliance Data System provides quarterly data on each plant's compliance status, along with every enforcement action faced by the plant. LEMIT is the annual tons of three criteria pollutants (particulates, sulfur dioxide, and nitrogen oxides) emitted by the plant, taken from EPA's National Emissions Data System.[13] CCOST is the cost per ton of capacity for the plant to comply with air pollution regulations, based on engineering cost estimates and the types of production equipment in use at each plant. We use various industry sources for plant capacity and employment, along with government data on county employment and unemployment, to construct the other plant-level control variables. For the firm-level data, Compustat provides data on the firm's employment (LEMPLOY) and gross rate of return (CASH), while compliance and capacity variables are aggre-

[11] Including a dummy for each state comes too close to including a variable for each plant, robbing many of our plant specific variables of significance. Instead, we use six state dummies, which cover about 75% of all observations.

[12] Readers interested in reviewing the specification of the plant closing equation, or its first- or second-stage estimations, are referred to Deily and Gray [7].

[13] There is little variation over time, so we use median emissions for the plant over all reported years; we add up the three pollutants in the absence of quantitative measures of their relative health risks.

gated from the plant-level data. (A data appendix, containing a more detailed description of variable construction and data sources, is available from the authors.)

The varied nature of our data creates some complications. The compliance measures appear quarterly, the enforcement data are continuous (each action is identified separately), and the firm- and plant-specific data are mostly annual or cross-section, respectively. Since our main focus is the plant- and firm-specific variables, and since enforcement activity is relatively infrequent (50% of the plant-quarters have no inspections and 25% have no enforcement actions), we aggregate the enforcement and compliance data into annual series, rather than estimating a quarterly model where only the two dependent variables have quarterly data.

The compliance variable that we create by aggregation, COMP, is qualitative: we define non-compliance for the year as being out of compliance in any of the four quarters of the year. (Requiring two, three, or four quarters out of compliance did not substantially change the reported results.) Since COMP is a qualitative variable, we estimate the compliance equation in both the first and second stages using logit.

The two enforcement measures, LTACT and LINSP, have zero values even after aggregation, (8% of the plant-years have no actions at all, and 15% have no inspections), so we use tobit rather than ordinary least squares to estimate the first and second stages of this equation. In both cases we take logarithms (more specifically, the log of one plus each enforcement measure, because of the zeroes) to minimize the effect of outliers. These specification decisions are not critical: adding a different constant to the number of enforcement actions before taking logs, using linear enforcement measures, or using ordinary least squares instead of tobit, gives us results similar to those presented here.

The enforcement and compliance equations are estimated for a sample of 41 steel plants over the years 1980 (the first year for which we have both enforcement and compliance data) through 1989. PCLOSE, the predicted plant-closing probability used in these equations, is estimated (in Deily and Gray [7]) for a larger sample of plants, some of which had closed by 1980. By including shutdowns that occurred before 1980 to estimate PCLOSE, we employ all available information to generate the best possible measure of a plant's likelihood of closing during the industry contraction.

IV. RESULTS

The first-stage estimations are shown in Table II. The variables LTACT, LINSP, and COMP are regressed on variables representing plant characteristics (location, product mix, plant capacity, the age of the plant's capital stock, and compliance cost), the local pollution level, the local labor market, firm characteristics, year dummies, and, in the case of the two enforcement variables, controls for cross-state variation in regulatory vigor. The equations are then used to generate predicted enforcement actions (PLTACT), predicted inspections (PLINSP), and a predicted compliance probability (PCOMP) for each plant each year.[14]

[14] The compliance equation does fairly well, predicting compliance status correctly 72% of the time. To get a rough ideal of the ‘‘fit’’ of the enforcement equations, we reran these estimations using ordinary least squares rather than tobit. The r^2 for LTACT was 46%, and for LINSP it was 28%.

TABLE II
First-Stage Regressions[a]

Variable	Dependent variable: LTACT Method: Tobit		Dependent variable: LINSP Method: Tobit		Dependent variable: COMP Method: Logit	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
C	−6.74**	0.89	−4.66**	0.84	2.81*	1.46
COAST[b]	−0.34	0.23	−0.21	0.22	−0.05	0.59
SHAPES[b]	0.36*	0.21	0.39*	0.22	−0.45	0.57
LPCAP	1.15**	0.12	0.69**	0.12	−0.79**	0.33
LCAPNEW[b]	0.37**	0.18	0.46**	0.19	0.16	0.52
CCOST	0.02**	0.007	0.02**	0.007	−0.006	0.02
ATTAIN	−0.25	0.16	−0.03	0.16	−0.59	0.41
LRELEMP	−0.08*	0.04	−0.14**	0.04	−0.29**	0.11
CNTYU	0.04	0.02	0.03	0.02	0.03	0.06
LEMPLOY	0.001	0.05	−0.07	0.05	−0.34**	0.14
STEEL	−0.008**	0.003	−0.002	0.003	−0.01*	0.008
CASH	−0.30	0.75	−0.21	0.75	−2.74	1.97
SINGLE	0.32**	0.13	0.46**	0.13	1.06**	0.34
LSTTACT	0.75**	0.08	—	—	—	—
LSTINSP	—	—	0.50**	0.09	—	—
Log likelihood	−428.39		−410.78		−173.61	
% Positive Observations	92		85		—	
% Correct Predictions	—		—		72	
n	326		326		326	

[a]All equations include year dummies.
[b]COAST is a dummy for coastal location; SHAPES is the percentage of plant capacity used for structural and bar products; and LCAPNEW is the percentage of plant equipment installed after 1959. Details are available from the authors.
*Significant at 5%, one-tail test.
**Significant at 2.5%, one-tail test.

Table III shows the second-stage results for the compliance variable. The coefficient of predicted enforcement is positive as expected, but not significant for either inspections or total actions. Lagged actual enforcement significantly increases compliance at a plant, whether measured as inspections or total actions. Based on these results, we conclude that enforcement activity increases compliance.

The coefficient of CCOST is negative and significant, indicating that higher costs for bringing a plant into compliance reduced the probability of its being in compliance. The coefficient of PCLOSE is also both negative and significant, indicating that firms were much less likely to bring marginal plants into compliance. The coefficient of LPCAP, however, is negative and significant; larger steel plants were less likely to be in compliance, ceteris paribus. Our data thus reveal no evidence that scale economies increased compliance at steel plants during this period. Instead, this result may reflect a stochastic element in compliance. If plants may slip out of compliance in a random way, due to equipment failure for instance, then those with more point sources might be more likely to have something wrong somewhere.

We find some evidence that firm characteristics affect compliance even after plant-level variation is controlled, but not in ways we expected. The coefficient of

TABLE III
Second-Stage Estimations: Compliance[a]

C	2.45**	2.55**	−0.49	0.99	3.46**	0.46
	(1.12)	(1.11)	(1.74)	(1.40)	(1.19)	(1.80)
PLTACT	0.25	—	—	—	0.27	—
	(0.27)				(0.27)	
PLINSP	—	0.17	—	—	—	—
		(0.34)				
DTACT	—	—	2.48**	—	—	2.47**
			(1.15)			(1.15)
DINSP	—	—	—	1.13*	—	—
				(0.63)		
CCOST	−0.04**	−0.04**	−0.03*	−0.03**	−0.05**	−0.04**
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
PCLOSE	−1.22**	−1.16**	−1.28**	−1.20**	−1.19**	−1.24**
	(0.55)	(0.55)	(0.54)	(0.53)	(0.54)	(0.53)
LPCAP	−1.00**	−0.80**	−0.84**	−0.80**	−0.90**	−0.73**
	(0.47)	(0.39)	(0.34)	(0.34)	(0.46)	(0.34)
LFCAP	−0.21	−0.22	−0.14	−0.14	−0.29*	−0.22
	(0.16)	(0.16)	(0.16)	(0.16)	(0.17)	(0.17)
STEEL	−0.004	−0.007	−0.001	−0.004	−0.006	−0.002
	(0.007)	(0.006)	(0.007)	(0.006)	(0.007)	(0.007)
CASH	−1.55	−1.58	−2.05	−1.87	−2.18	−2.68
	(1.93)	(1.91)	(1.97)	(1.96)	(1.83)	(1.86)
SINGLE	1.29**	1.28**	1.62**	1.50**	0.87**	1.24**
	(0.41)	(0.42)	(0.43)	(0.42)	(0.43)	(0.46)
FCOMPL	1.59**	1.61**	1.64**	1.61**	—	—
	(0.55)	(0.55)	(0.55)	(0.55)		
HFCOMP	—	—	—	—	0.78	0.98
					(0.92)	(0.94)
Log likelihood:	−173.47	−173.80	−170.40	−172.08	−177.48	−174.49
% Correct predictions	77	77	79	77	75	75

Note. Dependent-variable: COMP; estimation method: logit. $n = 326$
[a]Standard errors are in parentheses. Each regression includes year dummies.
*Significant at 5%, one-tail test.
**Significant at 2.5%, one-tail test.

LFCAP is negative but usually insignificant, providing no evidence of firm-level scale economies in compliance. The variable STEEL always has the expected negative coefficient, indicating that plants owned by less diversified firms were less likely to be in compliance, but again the coefficient is insignificant. The coefficient of CASH is unexpectedly negative, implying that firms with a higher gross rate of return were less compliant at individual steel plants. This estimate may be a result of the generally low profits earned by steelmakers in the 1980s: due to the industry's decline, possibly only diversified firms had access to cheaper funds. Again, however, the estimates are not significant.

The coefficient on the single-plant dummy SINGLE is positive rather than negative, and significant, indicating that steel plants owned by single-plant firms were more likely to be in compliance than steel plants owned by multi-plant firms. The single-plant firms tended to be smaller firms; if a single-plant firm's senior management was more likely to live in or near the community where their plant was located, then their greater compliance rate may have arisen from a desire to avoid any embarrassment that non-compliance might involve.[15]

Finally, the variables FCOMPL and HFCOMP are positive as expected, and in the case of FCOMPL, significant. (The coefficient of AFCOMP is positive and insignificant; these results are available from the authors.) Our estimates suggest a general ‘‘attitude’’ toward compliance: even after other sources of plant- and firm-related variation are controlled, a firm was more likely to be in compliance at any given steel plant if its compliance rate at other steel plants in the previous period was higher.

The second-stage estimations of the enforcement equation are shown in Table IV. The coefficient of PCOMP is negative, as expected, and always significant, whether enforcement is measured as total actions (LTACT) or as inspections only (LINSP). The impact is larger for total actions, as expected. Lagged compliance, COMPL, has a negative effect as well, but is significant only when enforcement is measured by total actions.

The variables, LEMIT, ATTAIN, and PCLOSE perform as expected, and their coefficients are frequently significant. The coefficient of CCOST is never significant: we find no evidence that regulators considered compliance cost when allocating enforcement activity across plants. As in our previous paper, the coefficient of LRELEMP is usually negative and significant, but the local unemployment rate, CNTYU, is positively and significantly related to enforcement. These two results imply that while large local employers felt less enforcement pressure, more enforcement activity was directed toward plants located in higher unemployment areas.

The coefficient of the firm-size variable LEMPLOY is mostly negative as expected, and frequently significant, implying that regulators exerted less pressure against larger corporations. The coefficient of STEEL is negative as expected, and significant, but the coefficient CASH is also negative, rather than positive as expected, and is significant. These estimates imply that diversified firms with lower gross profit rates received more regulatory attention than did specialized firms with high gross profits.

With respect to regulators' response to cooperation at the firm level, the coefficient of the lagged firm compliance variable, FCOMPL, is mostly negative as expected, but never significant. However, the coefficients of both HFCOMP and AFCOMP are positive, and in the latter case usually significant, as is the coefficient of the dummy variable SINGLE. These results imply that, other things equal, regulators exerted *more* pressure against single-plant firms, and that, while compliance at other plants in the recent past may have reduced current regulatory pressure, plants owned by firms with higher compliance rates historically, or over the entire period, received greater regulatory attention. This could indicate a tendency for regulators to exert pressure on firms that are more likely to respond without costly legal battles, a strategy that increases the return to noncompliance.

[15]As discussed earlier, the coefficient of SINGLE may also be affected by the imputations for missing firm-level data. Also, since state agencies are responsible for the bulk of environmental regulation enforcement, it is possible that any positive externalities a firm might garner from compliance are limited to other plants in the same state. To investigate further, we added an additional dummy that equaled one if a firm had no other plants in the same state. The coefficient of this variable was positive rather than negative as expected, but small and never significant.

TABLE IV

Second-Stage Estimations: Enforcement[a]

Dependent variable	LTACT[b]	LTACT	LTACT	LINSP	LINSP	LTACT	LINSP	LTACT	LINSP
C	4.41**	−2.14	−8.19**	−1.54	−5.13**	−2.35	−1.92	−2.16	−1.67
	(1.26)	(1.41)	(0.99)	(1.31)	(0.90)	(1.43)	(1.32)	(1.41)	(1.29)
PCOMP	−3.80**	−5.24**	—	−3.14**	—	−5.28**	−3.15**	−5.37**	−3.35**
	(0.92)	(0.82)		(0.83)		(0.82)	(0.82)	(0.82)	(0.82)
COMPL	—	—	−0.44**	—	−0.12	—	—	—	—
			(0.13)		(0.13)				
LEMIT	0.05	0.21**	0.37**	0.09	0.20**	0.21**	0.11	0.21**	0.10
	(0.07)	(0.07)	(0.06)	(0.07)	(0.06)	(0.07)	(0.07)	(0.07)	(0.07)
ATTAIN	−0.48**	−0.81**	−0.34**	−0.32*	−0.02	−0.79**	−0.28*	−0.76**	−0.22
	(0.18)	(0.17)	(0.15)	(0.17)	(0.15)	(0.17)	(0.17)	(0.17)	(0.17)
CCOST	−0.005	−0.007	−0.001	−0.002	0.001	−0.007	−0.002	−0.005	0.001
	(0.008)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
PCLOSE	0.01	−0.87**	−1.18**	−0.94**	−1.08**	−0.89**	−0.96**	−0.84**	−0.86**
	(0.23)	(0.21)	(0.21)	(0.21)	(0.21)	(0.21)	(0.21)	(0.21)	(0.21)
LRELEMP	−0.24**	−0.39**	−0.17**	−0.34**	−0.20**	−0.41**	−0.36**	−0.42**	−0.38**
	(0.07)	(0.06)	(0.04)	(0.06)	(0.04)	(0.06)	(0.06)	(0.06)	(0.06)
CNTYU	0.05**	0.08**	0.06**	0.06**	0.04*	0.08**	0.06**	0.09**	0.06**
	(0.03)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
LEMPLOY	−0.33**	−0.34**	0.01	−0.24**	−0.03	−0.33**	−0.24**	−0.34**	−0.26**
	(0.08)	(0.08)	(0.06)	(0.08)	(0.06)	(0.08)	(0.08)	(0.08)	(0.08)
STEEL	−0.02**	−0.02**	−0.004	−0.008*	0.003	−0.02**	−0.007	−0.02**	−0.008*
	(0.005)	(0.004)	(0.003)	(0.004)	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)
CASH	−1.96**	−3.21**	−0.09	−1.97**	−0.10	−3.16**	−1.96**	−3.16**	−1.95**
	(0.92)	(0.89)	(0.78)	(0.90)	(0.77)	(0.89)	(0.89)	(0.89)	(0.88)
SINGLE	0.73**	1.33**	0.24	1.06**	0.36**	1.42**	1.17**	1.51**	1.36**
	(0.27)	(0.24)	(0.16)	(0.24)	(0.15)	(0.24)	(0.24)	(0.25)	(0.25)
FCOMPL	−0.18	−0.12	−0.11	0.06	0.03	—	—	—	—
	(0.22)	(0.21)	(0.22)	(0.22)	(0.22)				
HFCOMP	—	—	—	—	—	0.21	0.59*	—	—
						(0.35)	(0.35)		
AFCOMP	—	—	—	—	—	—	—	0.39	0.93**
								(0.33)	(0.32)
LSTTACT	—	0.86**	0.86**	—	—	0.86**	—	0.84**	—
		(0.09)	(0.09)			(0.09)		(0.09)	
LSTINSP	—	—	—	0.61**	0.57**	—	0.61**	—	0.58**
				(0.09)	(0.09)		(0.09)		(0.09)
Log likelihood	−420.49	−423.10	−436.74	−407.64	−414.25	−423.07	−406.31	−422.56	−403.61

Note. Estimation method: tobit. $n = 326$.
[a]Standard errors are in parentheses. Each regression includes set of year dummies.
[b]Equation includes the state dummies.
*Significant at 5%, one-tail test.
**Significant at 2.5%, one-tail test.

Again, however, we must be cautious in evaluating the SINGLE coefficient since it may reflect imputations for missing firm-level data. Further, the positive relationship between enforcement and AFCOMP may reflect reverse causality: firms facing more enforcement currently may be more likely to comply at their other plants in the future.[16]

[16] We searched further for a reputation effect on enforcement by recreating FCOMPL, HFCOMP, and AFCOMP to reflect compliance behavior only at a firm's other plants within the same state. The coefficient of HFCOMP was significant, and again it was positive; the other variables were not significant. We also added a dummy that equalled one if the firm had no other plants in the same state. This dummy was significantly positive, indicating that plants owned by firms with multiple plants in a state faced less enforcement, irrespective of the compliance rates at those plants. This result may reflect a state-level political effect on enforcement.

We performed various diagnostic tests on both the compliance and enforcement equations. Tests for multicollinearity among the explanatory variables showed that, although several of the variables were fairly highly correlated, only the predicted compliance and predicted enforcement measures had their standard errors substantially inflated by multicollinearity. This would tend to strengthen our results, and may help explain why predicted enforcement had little impact in the second-stage compliance equation. There is evidence of autocorrelated residuals in both equations, but re-estimating the second-stage equations using ordinary least squares and correcting for autocorrelation did not change our major results about the interaction between compliance and enforcement.

We also tested some of the sets of explanatory variables in the second-stage equations for joint significance, using likelihood ratio tests. The year dummies are always significant in the enforcement equations, but sometimes fall short of significance in the compliance equations. The set of state dummies used in the second-stage enforcement equation are significant, but their inclusion tends to capture much of the effects of fixed-plant characteristics, particularly PCLOSE and LEMIT. Therefore we primarily report results that use the state enforcement variables LSTTACT and LSTINSP, rather than state dummies.

V. CONCLUSION

Our estimates show that the compliance decisions of integrated steel firms were affected by the enforcement decisions of air pollution regulators. Whether measured as total enforcement actions or as inspections only, enforcement, in particular lagged enforcement, increased compliance at steel plants. In addition, the plant's future viability and the cost of bringing it into compliance also influenced a firm's compliance decision as expected. The one surprising result in this regard was our discovery that larger steel plants were less rather than more likely to be in compliance.

Firm characteristics have surprisingly little impact on compliance: neither firm size, diversification, nor gross cash flows were significant. We find that single-plant firms were more likely to be in compliance, while we had expected multi-plant firms to have a greater incentive to invest in a reputation for firm-wide compliance. However, we do find evidence of a residual corporate ''attitude'' toward compliance: even after controlling for plant and firm characteristics, firms with higher compliance rates in other plants in the previous year were more likely to comply.

We also find that compliance behavior influenced enforcement decisions. Steel plants anticipated to be in compliance faced less enforcement, measured either by total enforcement actions or by inspections. As with compliance, enforcement decisions were influenced as expected by plant-level characteristics and behavior: regulators directed less pressure toward plants expected to be in compliance, toward plants expected to close, and toward plants in attainment areas, while exerting more pressure on plants producing large absolute amounts of pollution, irrespective of their compliance status. Local labor market conditions had mixed effects, with less enforcement at plants that were large employers in the area, but more at plants located in counties with high unemployment rates.

Firm characteristics had significant impacts on enforcement, although the signs were not always as expected. Larger firms, and firms specialized in steelmaking, faced less enforcement, suggesting regulator sensitivity to firms' political power or to their financial distress, but firms with higher gross profit rates also faced less enforcement. Firms that owned only one steel plant and firms with a higher compliance rate over the entire period faced more enforcement. This may reflect a willingness on the part of regulators to pressure more cooperative firms, but runs counter to the results for plant-specific compliance, where more compliant plants faced less enforcement.

Our results indicate the importance of treating compliance and enforcement decisions together, and of including both plant and firm characteristics in the analysis. The interactions between compliance and enforcement decisions, and the effects of plant characteristics on both decisions, generally went in the expected directions. The effects of firm characteristics were less predictable and point toward the need for further work in this area, perhaps by examining comparable data for other, non-declining, industries.

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