

**THE CLEAN AIR ACT AMENDMENTS AND
FIRM INVESTMENT IN POLLUTION ABATEMENT EQUIPMENT**

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ABSTRACT

The command-and-control approach to environmental regulation requires that firms install prescribed technologies to meet specified goals. However, environmental regulations change frequently; in addition, the enforcement agency cannot perfectly monitor firm compliance. We examine the impact of uncertainties surrounding the enactment and the enforcement of the Clean Air Act Amendments of 1990 on firm investment in air pollution abatement equipment. We find that our measures of the likelihood of CAAA passage clearly affect a firm's investment in pollution equipment. Enforcement actions also affect a firm's investment, but these effects are weaker and are statistically significant only after enactment.

I. INTRODUCTION

The command-and-control approach to environmental regulation generally used by regulatory agencies like the U.S. Environmental Protection Agency (EPA) requires that affected firms install prescribed technologies to meet specified goals. The firm's decision to install pollution abatement capital is therefore essentially a decision to comply with environmental regulations. Such investment expenditures can be quite significant. The U.S. Bureau of the Census (1996) reports that in 1993 U.S. manufacturing industries spent \$7.5 billion on pollution abatement capital, in response to various environmental regulations.

However, environmental regulations change, often frequently and sometimes unpredictably. Between 1955 and 1990 at least ten major federal statutes were introduced with the goal of mitigating the effects of air pollution, culminating in the passage of the Clean Air Act Amendments (CAAA) of 1990. In the face of such changing regulations, firms may not know with certainty whether any environmental regulations will actually be enacted, and they may not know with certainty what provisions will be included in any legislation that is actually passed. All of this affects a firm's perception of the likelihood of any change in environmental regulations. Such uncertainty obviously complicates a firm's choices in a number of dimensions, but it especially complicates a firm's investment decision, in light of the significant adjustment costs and the investment irreversibility that capital expenditures entail (Perry's Chemical Engineer's Handbook 1984; Peters and Timmerhaus 1991). As a result, a firm faces a real concern that its current investment may be either too much or too little to meet future regulations. This uncertainty may be one reason why some firms claim that they wish to be good environmental corporate citizens by over-complying with current environmental regulations, a

response that may indicate the firms' desire to reduce the effect of uncertainty by undertaking sufficient current investment to meet possible future regulations.¹

Many studies have examined a firm's compliance with environmental regulations (Downing and Kimball 1982; Fuller 1987; Chua, Kennedy, and Laplante 1992; Burby and Paterson 1993; Harrison 1995). Some studies have also examined a firm's investment in pollution abatement capital in response to environmental regulations (Pashigian 1984; Joskow and Rose 1985; Gray and Shadbegian 1997; Seldon, et al. 1994). Others have examined the effect of enforcement on pollution abatement investment (Magat and Viscusi 1990; Seldon, et al. 1994). These studies typically find that more stringent environmental regulations lead to the use of cleaner technologies and that enforcement is a key determinant in a firm's compliance with pollution abatement capital. However, the effect of the likelihood of passage of future regulations on current pollution abatement investment has seldom been examined.²

In addition, firm compliance with regulations must be monitored by the regulating agency, and such monitoring is imperfect. A firm does not know whether it will be inspected; if inspected, the firm does not know whether it will be found guilty of a violation; and, if inspected and found guilty of noncompliance, it does not know how much of a fine it must pay for its noncompliance. The coupling of uncertainty about the passage of future regulations with imperfect monitoring by the enforcement agency, and their combined effects on firm investment in pollution abatement capital, has also not been examined.³

In this paper we estimate the effects on firm investment in pollution abatement capital both of a firm's perception of the likelihood of a change in environmental regulations and of imperfect monitoring by the EPA, using the debates surrounding the passage of the CAAA as an example of activities that created the uncertainties. The Amendments constituted one of the

major pieces of environmental legislation of the last two decades, and issues about its enactment were discussed for nearly a decade. We construct several measures of the likelihood of CAAA passage and also several measures of the stringency of enforcement actions by the EPA for the periods before and after the CAAA of 1990, and we then estimate the effects of these measures on capital expenditures made by the “average firm” in sixty-two manufacturing industries. Our empirical results indicate that the likelihood of CAAA passage positively affects an average firm’s investment in pollution abatement capital. EPA enforcement actions also affect a firm’s investment in pollution abatement capital, but the results are somewhat mixed. For example, fines have a positive and significant impact on a firm’s investment but only after the enactment of the CAAA; also, an increase of ten percent in the number of inspections increases firm investment by only one percent before the enactment of the CAAA and by roughly ten percent after the enactment, but the effects are only statistically significant after enactment.

The next section summarizes the period surrounding the passage of the CAAA of 1990, and also summarizes the main features of the Amendments. Section III presents our theoretical model of firm investment, as well as our empirical implementation of the model. Results are discussed in section IV, and summary and conclusions are in the final section.

II. THE CLEAN AIR ACT AMENDMENTS OF 1990

The Clean Air Act Amendments of 1990 were enacted on November 15, 1990, after roughly a decade of political debate. Their passage was uncertain for much of this period, only becoming likely during the latter years of the 1980s. Their content remained unresolved until the Amendments were agreed upon in final discussions between individuals in the House, the Senate, and the Bush Administration.

In this section we summarize the discussion preceding the passage of the Amendments, in order to convey the nature of those factors that could affect firm perceptions of the likelihood of CAAA passage. We also present the main features of the CAAA, including their major enforcement mechanisms, in order to indicate the significance of the CAAA for firm capital expenditures and to explain the nature of imperfect monitoring by the regulatory agency that is present in environmental regulation.

The CAAA debate began in the early 1980s. On July 17, 1981, President Ronald Reagan signed into law the Steel Industry Compliance Extension Act of 1981, whose purpose was to provide the steel industry an extension of no more than three years for compliance with the Clean Air Act Amendments of 1977. In signing the law, President Reagan stated that “this act...is a symbol of the administration’s commitment...to cast aside the over-zealous and unnecessary regulation that has shackled the most productive forces in our economy” (Environmental and Natural Resource Policy Division, Congressional Research Service, Library of Congress, p. 10583). Subsequent attempts to weaken further the Clean Air Act Amendments of 1977 largely proved to be unsuccessful, despite the coalition of the Reagan Administration, the automobile industry, Senate Majority Leader Robert Byrd (D-West Virginia), and Representative John Dingell (D-Michigan).⁴ Nevertheless, this coalition was largely able to prevent the enactment of new environmental regulations, often even choking off efforts to bring new laws to a floor vote (Harris and Milkis 1996).

Legislative efforts to reauthorize the Clean Air Act Amendments were rejuvenated in 1987, and the prospect of passing the Amendments brightened after the 1988 elections. Newly elected President George Bush pledged to be an “environmental president”, and George Mitchell (D-Maine) replaced Byrd as Senate Majority Leader.⁵ Even so, passage remained uncertain, and

several key concessions had to be made. Mitchell had to compromise on acid rain provisions, giving up mandates for scrubbers in exchange for tradable permits for sulfur dioxide emissions. More importantly, Representative Henry Waxman (D-California) and Dingell had to compromise on provisions relating to mobile sources.

Throughout, there was much uncertainty about the specific provisions that any Amendments would actually contain. For example, bills originating from the House of Representatives focused mainly on criteria pollutant control measures. Further, moves to strengthen “nonattainment” programs were introduced via reclassification of nonattainment regions into tiered nonattainment regions, where area designations were based on the magnitude of violation of the primary ambient air quality standards.⁶ A fee collection system was also introduced to pay for these programs, and operating permit programs for nonattainment regions were introduced. In contrast, the Senate focused on curbing the emission of hazardous pollutants. The Senate proposed bills to prod the EPA into listing hazardous pollutants faster than it had before in early 1980s. However, the idea of a congressionally mandated listing of hazardous air pollutants did not appear on the legislative scene until 1987. Programs to deal with accidental release of hazardous air pollutants were introduced in 1985, but did not gather much impetus until 1987. Nonattainment issues were also tackled in the Senate, but not nearly to the same extent as in the House.

More broadly, the major battles in Congress occurred over how stringent any new proposals should be, and not so much over what general areas the proposals should address. For example, the specific reduction target for sulfur dioxide emission was debated vigorously, with the target goal ranging from 6 million tons to 10 million tons, but there was little argument over the basic need to specify some reductions.

In sum, the CAAA of 1990 emerged after a decade of political debate. Their passage was uncertain for much of this period, only becoming likely during the latter years of the 1980s. Their content remained unresolved until final discussions between individuals in the House, the Senate, and the Administration. There is little question that firms were making investment decisions over this period without knowing precisely the outcome of the legislative process.

The Clean Air Act Amendments of 1990 that were finally passed were sweeping in their scope. The Amendments have eleven titles that govern stationary and mobile sources of air pollution, and common and hazardous air pollutants, with four titles of particular relevance for stationary sources of air pollution, and so for firm investment in abatement capital.

Title I (Provisions for Attainment and Maintenance of Ambient Air Quality Standards) extended attainment deadlines and recategorized nonattainment areas for ozone, carbon monoxide, and particulates.⁷ Nonattainment deadlines varied, depending on the severity of noncompliance. The CAAA recategorized the nonattainment regions based on the severity of violation.⁸ Importantly, the definitions for major sources and offset requirements became much more stringent.

Title III (Hazardous Air Pollutants) was a congressional response to what was perceived as a very slow EPA response to the Clean Air Act Amendments of 1977 mandate (Quarles and Lewis, Jr. 1991). Congress increased the scope of emission standards by listing 189 hazardous air pollutants to be regulated, and mandated the EPA to establish emission standards and to create a list of sources of hazardous air pollutants to be regulated within a year from the date of enactment of the CAAA. Title III also tightened the control over new or modified sources of hazardous pollutants.

Title V (Permits) closed one of the biggest loopholes in federal environmental regulations. Before the 1990 Amendments, new or modified sources were stringently regulated, requiring firms to install a “Best Available Control Technology” or to attain a “Lowest Achievable Emission Rate” via granting or withholding construction permits. However, non-modified existing sources were largely exempted from these regulations via grandfathering provisions (Schulze 1993). Title V changed this, and required all sources of air pollution to be regulated. It also created a fee collection system to cover all reasonable (direct and indirect) costs required to develop and to administer the permit program.

One last set of provisions in the CAAA related to its enforcement (*Title VII – Enforcement*). These provisions substantially increased the severity of the punishments for violations, and made almost all knowing violations subject to criminal penalties (Quarles and Lewis, Jr. 1991).⁹

However, enforcement procedures remained, and still remain, imperfect. A firm does not know whether it will be inspected, whether it will be found guilty of a violation if inspected, or how much of a fine it must pay if inspected and convicted. These imperfections imply another avenue by which firms can deal with environmental regulations: the firms can ignore the various mandates, and hope that they will not be caught, convicted, or fined.

Firms are therefore required to make substantial investment decisions in pollution abatement in the face of many uncertainties. The next section presents our methodology for analyzing these investment decisions.

III. THEORETICAL AND EMPIRICAL SPECIFICATION

The Firm Investment Decision

Consider a competitive, risk-neutral, profit-maximizing firm that makes a decision to produce output and to invest in pollution abatement capital when the firm knows only the likelihood that environmental regulations will be enacted and when there is imperfect monitoring by the enforcement agency of firm compliance with any regulations. The firm faces a convex production cost function, and, similarly, its investment cost function is assumed to be a convex function of investment in pollution abatement capital. Investment is assumed to be irreversible, and is also assumed to take time, being in place only in the period after the investment is made.¹⁰ The pollution abatement capital depreciates at a constant rate.

A three-period time horizon is assumed. In period 1, the firm decides on the levels of production and of investment in pollution abatement capital, given that the probability of enactment of new environmental regulations in period 2 is fixed, known, and predetermined. If the regulation is enacted at the start of period 2, then a binding emission standard is imposed on the firm in period 2 and the subsequent period; if the regulation is not enacted, then there is no emission standard in periods 2 or 3 (or in period 1). At the beginning of period 2, the regulation is either enacted or not. After observing this resolution, the firm chooses the level of production and investment in pollution abatement capital in period 2. In period 3, the firm simply chooses the amount of output to produce.¹¹

Even if the new environmental regulations are enacted, the firm will be found to be noncompliant only if audited; that is, there is imperfect monitoring of firm compliance with any emissions standard. Following the standard economics-of-crime approach (Becker 1968), if the firm is audited and found to be noncompliant, the firm is subject to a per unit fine. The probability of audit is assumed to be fixed, known, and predetermined.

Ignoring corner solutions, the firm's optimization generates the result that the firm the firm invests in period 1 such that the marginal cost of investment equals the expected discounted fine forgone in periods 2 and 3. It is important to note that the firm will spread its investment cost over time because it is cheaper to do so than wait for the uncertainties to be resolved.¹²

It is straightforward but tedious to generate the comparative statics of the firm's optimal investment responses. Of perhaps most interest here, an increase in the likelihood of regulation enactment will increase the amount of (period 1) investment in pollution abatement equipment by the firm as the firm increases its investment to meet the anticipated higher future standards. Similarly, an increase in the audit rate of the enforcement agency will increase investment via the standard deterrent effect of audits, as will an increase in the fine rate of the enforcement agency.¹³ Other variables (e.g., the depreciation rate, the discount rate, the product price, the cost of production, the cost of investment) have the expected impacts on firm investment. It should be noted, however, that these comparative statics responses assume that the firm cannot exit the industry. The possibility of exit clouds somewhat the theoretical results, and makes empirical examination especially important.

This optimization generates investment demand functions for pollution abatement capital that differ before and after the regulatory change. In period 1, or **before enactment**, the firm must consider both the likelihood of regulation passage and the enforcement actions of the agency (the fine rate and the probability of audit) in making its decisions; **after enactment** in periods 2 and 3, only enforcement activities are relevant to the firm's decisions. The next subsection discusses the empirical specification of these investment demands.

Empirical Specification

Consider an average firm in an industry. **Before enactment** of the regulatory change, the demand for pollution abatement capital by the average firm in industry i in any period t depends upon the expected levels over time of enactment probabilities θ_{it} , audit rates v_{it} , and unit fines f_{it} , as well as a vector \bar{Z}_{it} of other factors specific to the average firm in the industry. Similarly, the firm's demand for pollution abatement capital **after enactment** depends upon the same factors except for the enactment probabilities, since the likelihood of enactment is obviously no longer relevant after enactment. Assuming for simplicity that these investment demand functions are linear, that the firm has rational expectations, and that the expected values of the enactment probability, the audit rate, and the fine rate for firm i in period t always equal their actual values, then these demands can be written as:

$$(1) \quad \textbf{Before Enactment:} \quad I_{it} = \bar{\alpha} + \alpha_i + \alpha_1 \theta_{it} + \alpha_2 v_{it} + \alpha_3 f_{it} + \bar{\gamma} \bar{Z}_{it} + \varepsilon_{it}$$

$$(2) \quad \textbf{After Enactment:} \quad I_{it} = \bar{\beta} + \beta_i + \beta_1 v_{it} + \beta_2 f_{it} + \bar{\lambda} \bar{Z}_{it} + u_{it},$$

where I_{it} denotes average firm investment, $(\bar{\alpha} + \alpha_i)$ equals an average firm-specific intercept before the regulation enactment, $(\bar{\beta} + \beta_i)$ equals an average firm-specific intercept after the regulation enactment, and ε_{it} and u_{it} are the respective error terms. Equations (1) and (2) form the basis for our empirical estimation of the impact of the Clean Air Act Amendments of 1990 on firm investment. We use fixed-effects, generalized least squares (GLS) estimation, applied separately to observations before and after the regulatory change with the average firm in an industry as the unit of observation.

Variables and Data

We examine the investment in air pollution abatement capital of average firms in 62 manufacturing industries aggregated at the 3-digit standard industry classification (SIC), for the period 1988 to 1994. Given the enactment of the CAAA in November 1990, the pre-enactment effects of regulation and enforcement are examined with the investments for the three years 1988, 1989, and 1990 (e.g., before enactment); the post-enactment effect of enforcement action examined with data for the four years from 1991 to 1994. In total, there are 186 observations before enactment (or 62 industries times 3 years) and 248 observations after enactment.

We merge several data sets to examine the investment behavior of these industries: the Pollution Abatement Costs and Expenditures, the Policy Agendas Project data set, the National Environmental Scorecard, the Aerometric Information Retrieval System, and CompuStat information.

Until 1994, the Bureau of the Census conducted an annual survey of manufacturing firms to gauge a firm's investment in air pollution abatement capital, called the Pollution Abatement Costs and Expenditures (PACE). Firms of 20 or more employees were asked to report their investments in air pollution abatement capital. For 1994, a sample of approximately 17,800 firms was chosen. PACE information is used to construct the average firm's investment in pollution abatement capital (*Investment*), by dividing the air pollution capital expenditures by the number of emission sources in the industry.¹⁴ Also shown in Table 1 is the median firm's investment. A striking characteristic of the PACE data set is its highly skewed distribution. Before the enactment of the CAAA, the mean annual firm investment was \$122,281, while the median firm spending was roughly than half of this, or \$62,609; the same marked difference between the mean and the median continues after the enactment of the CAAA.¹⁵ There are four industries that invest in air pollution abatement capital much more heavily than other industries:

pulp and paper, chemicals, petrochemicals, and primary metals. To mitigate the skewed distribution, the firm's investment in air pollution capital is transformed in some estimations by a natural log function.

We measure the likelihood of CAAA passage with several proxy variables that reflect both the activities and the preferences of a key Congressional subcommittee, the Subcommittee on Health and the Environment of the Committee on Energy and Commerce. This Subcommittee played a vital role in the enactment of the CAAA due to its responsibility in holding "markup" meetings and hearings (Denzau and Mackay 1983; Olson 1994).¹⁶ These meetings and hearings are important to any legislation because they allow the committee to gather information and to build a coalition for or against legislation, hence setting an agenda for the legislation (Deering and Smith 1997). Table 2 summarizes the activities and preferences of this Subcommittee.

Subcommittee activity is measured by the number of hearings held by the Subcommittee (*Subcommittee Activities*), as tabulated by the Agendas Project Hearings through the Center for American Politics and Public Policy at the University of Washington.¹⁷ The efficacy of using the activities of the Subcommittee as a proxy variable for the likelihood of CAAA enactment is likely to depend on the length of relevant timeline. In comparison to less controversial issues, one would suspect that a complicated, far-reaching, and contentious issue such as air pollution regulation would generate many hearings to gather information, to build consensus, and to draft bills over the course of its legislative history. However, one would also expect a decrease in the number of hearings held annually by the Subcommittee as a political consensus arose. Given that only three years of hearing activities are examined, we hypothesize that the consensus aspect

may dominate the level of interest aspect, thus exhibiting a negative relationship with a firm's investment in pollution abatement capital.

Environmental preferences of the Subcommittee are measured by the average voting records of the subcommittee members. The League of Conservation Voters annually publishes the National Environmental Scorecard, whose purpose is to evaluate the environmental performance of the Congress through member voting records. Each member of the Congress is evaluated based upon his or her voting behavior on environmental bills. A member who is deemed friendly to the environment receives a higher score than a member who is deemed hostile to environmental issues, on a scale from 0 to 100. The salient environmental topics vary from year to year; however, given the interconnectedness of many environmental issues, this evaluation serves as a reasonable gauge of environmental preference of members of the Congress. We measure preferences by the average score of members of the Subcommittee on Health and the Environment (*Subcommittee Preferences*). A higher environmental preference of the Subcommittee members is assumed to increase the probability of CAAA enactment, and so should have a positive effect on firm investment.

We capture the effect of enforcement uncertainty with the Aerometric Information Retrieval System (AIRS) Facility Subsystem data, as summarized in Table 3. The number of inspections an average firm can expect to experience (*Inspections*) is assumed to equal the sum of the number of EPA and state conducted inspections (at level 2 or above) per industry divided by the number of firms that are major and minor sources in that industry. The fine an average firm can expect to pay (*Fines*) equals the total fine levied on an industry divided by the number of firms that are major and minor sources. A potential concern with *Inspections* and *Fines* is the possibility that they are endogenous, even though they are both constructed obtained from

industry-level data, not firm-level data. As discussed below, we test for endogeneity of these two variables, and we find that they are not endogenous.

As shown in Table 3, the AIRS data set is characterized by a highly skewed distribution, and we transform the variables in some specifications by a natural log function.¹⁸ The pulp and paper, chemical, petrochemical, and primary metal industries are inspected more frequently than other industries, and fines levied at these industries also tend to be larger. Table 3 clearly indicates the significant increase in fines after enactment of the Amendments; in contrast, the number of state and EPA inspections was virtually the same before and after enactment. As suggested by the comparative statics of the firm's decisions, the relationship between *Inspections* and *Investment* is expected to be positive, as is the relationship between *Fines* and *Investment*.

Other variables may affect a firm's investment in pollution abatement capital, such as the firm's stock of pollution abatement capital, the cost of investment, depreciation, the discount rate, the price of the final good, and the cost of production. These variables are included in the Z_{it} vector, and are constructed from several data sets.

We construct the firm's stock of air pollution abatement capital using the PACE data. The average firm's stock of air pollution abatement capital (*Capital Stock*) is calculated as the sum of industry investments over the period 1985 to 1994, divided by the number of emission sources in the industry. The calculated capital stock is depreciated using industry-specific proxies for depreciation rates.¹⁹ Like some of the other series, the capital stock data are highly skewed, and we adjust this variable in some specifications by a natural log transformation.

Due to the unavailability of data on the average firm's cost of investment, the depreciation rate, and the discount rate, we construct proxy variables using CompuStat data.

CompuStat data contain annual information on firm characteristics for publicly traded firms.²⁰

We aggregate these data by 3-digit SIC code and then divide by the number of sources in order to obtain information on average firms.

If capital projects are largely debt financed, then a firm's long-term interest expense as a percentage of its total long-term debt (*Investment Cost*) should proxy for the unit cost of investment. The ratio of a firm's short-term debt to its long-term debt (*Debt Ratio*) is used as a proxy for the industry's discount rate: if an industry has a high discount rate, then it should hold a low level of long-term debts relative to short-term debts, holding other things constant.

Depreciation is measured by the firm's total depreciation as a percentage of the total capital stock. The total cost of production is used as a proxy variable for the unit cost of production (*Production Cost*). The data for the price of the good sold by an industry (*Price*) come from the Producer Price Index.

The constructed variables are summarized in Table 4, which shows both the theoretical variables and their empirical counterparts. When appropriate, the variables are normalized by dividing by the numbers of firms that are emission sources.²¹

Econometric Issues

We employ a fixed-effects, generalized least squares (GLS) estimator. It is important to assume industry-specific intercepts that allow for industry-specific differences. Many firms differ in size, scale, and scope of operation; in particular, a firm that is pollution-intensive may invest differently than a firm that is not pollution-intensive.²²

All standard errors are corrected for the possible presence of heteroskedasticity.²³ We also assume that the GLS estimator has an AR(1) error structure in order to treat any possible

autocorrelation problem. Due to the short time horizon of three years before the CAAA, autocorrelation could not be effectively detected in the entire sample of industries. The Durbin-Watson statistic is 1.72 with the corresponding upper and lower bound p-value of 0.002 and 0.070;²⁴ at the p-value of 5 percent, the null hypothesis of absence of autocorrelation cannot be rejected. The autocorrelation problem with the fixed-effects estimates after the enactment of the CAAA is effectively detected and treated. The Durbin-Watson statistic of the fixed-effects estimates is 1.50 with the corresponding p-value of 0.00.²⁵

As noted earlier, we examined the potential endogeneity of *Fines* and *Inspections* using the standard Hausman test. Identification of *Inspections* was achieved by using the number of EPA Notice of Violations as an instrument; for *Fines*, the number of State Notice of Violations was used. Tests were conducted for each variable by itself, as well as for both variables together. All tests indicated that the variables are not endogenous.

The basic specifications that we report in Table 5 transform some of the variables by a natural log function. We have also estimated a large number of alternative specifications. For example, we have estimated specifications in which all variables enter linearly, without a log transformation. We have used the number of meetings of the entire House Committee (instead of the House Subcommittee) as a measure of activities. We have included the standard deviation of *Subcommittee Preferences* as an alternative (as well as in addition) to its mean level as a measure of preferences. We have estimated specifications in which we exclude both singly and as a group those variables whose signs are sometimes statistically insignificant in our basic specification. We also present estimation results in which we examine separately the responses of industries historically identified as heavy polluters (e.g., “dirty” industries) and all other “clean” industries. The “dirty” industries include the pulp and paper, chemical, petrochemical,

and primary metal sectors, or those industries that invest in air pollution abatement capital much more heavily than other industries; the “clean” industries include all other sectors. Overall, our results are largely unaffected. In particular, as we discuss next, the effects of the likelihood of CAAA passage on the average firm’s investment in pollution abatement equipment remain the same across our different specifications. *Subcommittee Preferences* continues to have a positive and statistically significant impact on investment, and *Subcommittee Activities* retains its negative and significant effect. Enforcement activities generally have the same effects across the different specifications, although these effects are not always statistically significant.²⁶

IV. ESTIMATION RESULTS

Our basic estimation results are presented in Table 5. Of primary interest are the effects on investment of the likelihood of enactment of the Clean Air Act Amendments. As expected, the environmental preferences of the Subcommittee on Health and the Environment, measured by *Subcommittee Preferences*, positively affect the average manufacturing firm’s investment in pollution abatement capital. When more environmentally friendly members of Congress sit on key subcommittees, the manufacturing firms increase their investments in pollution mitigating capital. More precisely, if the average environmental preference of the Subcommittee increases by one percentage point, then an average manufacturing firm increases its investment by approximately \$90,121. When “dirty” and “clean” industries are examined separately, the response of the average firm in “dirty” industries to *Subcommittee Preferences* is somewhat larger than that of “clean” industries (\$106,118 versus \$83,812).²⁷

The effect of activities of the Subcommittee on Health and the Environment (*Subcommittee Activities*) on a firm’s investment in pollution abatement capital before

enactment of the CAAA is negative. As the number of hearings decreases, signaling a consensus on enacting the Amendments, a firm's investment will increase. Indeed, if the number of hearings held by the Subcommittee decreases by 1 meeting, an average firm's investment will increase by \$8682, or by 7.1 percent.²⁸ Again, the response of the average firm in "dirty" industries is greater than that of a firm in "clean" industries, but only marginally so (\$8611 versus \$7726).

The effects of enforcement activities are somewhat weaker, at least before enactment. The audit rate (*Inspections*) generally has a positive affect the average firm's investment both before and after the enactment of the CAAA, but the impact on investment tends to be statistically significant only after enactment. The implied investment-audit rate elasticity for all industries is roughly 0.1 before the Amendments, and increases to more than one after passage, perhaps reflective of the much stricter post-Amendment enforcement regime; in terms of the magnitude of investment response, an increase by 1 unit in the number of inspections increases the average firm's investment by \$7683 before enactment and by \$156,249 after enactment. The post-Amendment impact on investment by an average firm in a "dirty" industry is significantly greater than the impact on a firm in a "clean" industry. For example, an increase by 1 unit in the number of inspections increases the investment of an average firm in a "dirty" industry by over \$318 thousand, but a firm in a "clean" industry increases investment by only \$112 thousand.

In a similar manner, *Fines* has a positive effect on investment but, again, the response is statistically significant only after enactment. Post-CAAA, an increase of \$1 in fines increases the average firm's investment across all industries by only \$3. For "dirty" industries the response is \$4 after enactment, while for "clean" industries the response is roughly \$3. It is of some interest that the investment response to inspections is much larger than the response to fines.

After enactment of the CAAA, an increase in fines by 10 percent will generate an increase in pollution abatement capital by the average firm of less than three percent, in contrast to the roughly unit investment elasticity for inspections.²⁹ This differential post-Amendment response between fines and inspections is present both for “dirty” and for “clean” industries.

Other variables generally have expected impacts on investment in pollution abatement equipment, although their effects are not always statistically significant. An increase in *Investment Cost* reduces *Investment*, especially for “dirty” industries after enactment, as does the presence of a larger accumulated *Capital Stock* and a larger *Debt Ratio*. In contrast, a higher product *Price* generally increases investment, as does a larger *Depreciation* rate. These responses are largely consistent with expectations.

V. SUMMARY AND CONCLUSIONS

Our empirical results clearly indicate that the likelihood of a regulatory change affects an average firm’s investment in pollution abatement capital. Using the preferences and the activities of a key committee in the legislative process to gauge the probability of regulatory change, we find that a change in preferences toward more environmentally friendly members generates an increase in firm investment in pollution abatement capital. We also find that a decrease in the number of hearings held by the committee, thereby signaling a consensus on the enactment of the proposed bill, generates an increase in investment as firms anticipate the eminent passage of a bill that will require more pollution abatement capital. These responses are large and statistically significant, and also are larger for the average firm in a “dirty” industry than in a “clean” industry.

The effect of regulatory agency enforcement activities on a firm's investment is present but is not as strong, at least before enactment of the regulatory change. As the probability of audit increases or as the dollar magnitude of the fine increases, investment in pollution abatement capital generally increases, but these relationships are only statistically significant after the enactment of the CAAA and the accompanying greater stringency of the post-Amendment enforcement regime. Firm responses are significantly greater to a change in inspection rates than to the monetary cost of fines.

In sum, the difficulty of firms in predicting either the activities of Congressional committees or those of watchdog agencies has a significant impact on firm investment activities. The resolution of these uncertainties would obviously have the opposite effect on investments. Of course, if increasing firm investment in pollution abatement equipment is desired by those in Congress and the EPA, it may well be that the maintenance of these uncertainties is intentional.³⁰

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Table 1: Firm Investment in Pollution Abatement Capital (in dollars)

	<i>Investment:</i> Mean Firm Investment (Standard Deviation)	Median Firm Investment
Before Enactment of CAAA	\$122,281 (\$154,787)	\$62,609
After Enactment of CAAA	\$158,033 (\$240,291)	\$71,732

Table 2. Activities and Preferences of the Subcommittee on Health and the Environment

Year	<i>Subcommittee Activities:</i> Number of Hearings Held by the Subcommittee of Health and the Environment	<i>Subcommittee Preferences:</i> Average Environmental Rankings of Members of the Subcommittee of Health and the Environment
1988	0	55.94
1989	5	57.62
1990	1	57.95

Table 3. Enforcement Profile Before and After the CAAA

	Before Enactment		After Enactment	
	Mean (Standard Deviation)	Median	Mean (Standard Deviation)	Median
Number of EPA and State <i>Inspections</i> Per Firm	1.528 (0.961)	1.399	1.279 (0.466)	1.218
<i>Fines</i> Per Firm (in dollars)	\$348.61 (\$1313.90)	\$4.53	\$1520.38 (\$5494.90)	\$205.84

Table 4. Theoretical Variables and Proxy Variables

Theoretical Variable	Proxy Variable	Description
I_{it}	<i>Investment</i>	The level of air pollution capital expenditures divided by the number of firms that are major and minor sources of air pollution, measured in millions of dollars per firm
θ_{it}	<i>Subcommittee Preferences</i>	The environmental ranking of House subcommittee members, based on their past voting records
θ_{it}	<i>Subcommittee Activities</i>	The number of hearings held by the Subcommittee on Health and the Environment
v_{it}	<i>Inspections</i>	The sum of the number of EPA and state inspections divided by the number of major and minor sources in the industry
f_{it}	<i>Fines</i>	The total fines divided by the number of firms, measured in dollars per firm
---	<i>Investment Cost</i>	The long-term interest expense as a percentage of the total long-term debt, divided by the number of firms
---	<i>Debt Ratio</i>	The ratio of debt due in one year over the long-term debt, divided by the number of firms
---	<i>Depreciation</i>	The sum of depreciation and amortization, expressed as a percentage of the total capital stock, divided by the number of firms
---	<i>Capital Stock</i>	The sum of air pollution capital expenditures depreciated at an industry-specific depreciation rate, measured in millions of dollars per firm
---	<i>Price</i>	Producer Price Index in each industry over time
---	<i>Production Cost</i>	The cost of final goods sold divided by the number of firms, measured in millions of dollars per firm

Table 5. The Determinants of Firm Investment in Pollution Abatement Equipment: Natural Log Specifications

Independent Variable	Dependent Variable: <i>ln (Investment)</i>					
	Before Enactment			After Enactment		
	All Industries	“Dirty” Industries	“Clean” Industries	All Industries	“Dirty” Industries	“Clean” Industries
<i>Subcommittee Preferences</i>	0.737*** (4.457)	0.801** (2.050)	0.716*** (3.525)	NA	NA	NA
<i>Subcommittee Activities</i>	-0.071** (2.281)	-0.065 (-1.063)	-0.066* (-1.659)	NA	NA	NA
<i>ln (Inspections)</i>	0.096 (0.195)	1.600 (1.031)	0.113 (0.237)	1.265 (0.760)	1.478*** (-7.343)	1.283*** (5.040)
<i>ln (Fines)</i>	-0.022 (-0.909)	-0.040 (-0.667)	-0.035 (-1.030)	0.027*** (4.289)	0.022** (2.488)	0.043*** (5.591)
<i>Investment Cost</i>	-401.955* (-1.856)	-766.180 (-1.094)	-347.553 (-1.030)	-140.764*** (-3.901)	-620.055*** (-3.600)	-187.951*** (3.358)
<i>Debt Ratio</i>	15.777 (0.754)	22.636 (1.249)	-9.753 (-0.163)	-12.019 (-0.367)	-14.123*** (-4.486)	-14.700*** (2.872)
<i>ln (Depreciation)</i>	1.591*** (3.615)	0.925 (1.106)	1.852** (2.503)	0.978*** (7.559)	2.226*** (15.945)	-0.557*** (6.827)
<i>ln (Capital Stock)</i>	-0.923*** (-4.141)	-1.023** (-2.087)	-0.899*** (-3.418)	-0.584*** (-11.876)	-0.749*** (11.612)	-0.554*** (7.359)
<i>Price</i>	2.539 (1.613)	3.499 (1.441)	1.572 (0.531)	2.029*** (4.493)	-0.332 (-0.647)	1.157*** (3.838)
<i>ln (Production Cost)</i>	0.331 (0.863)	0.077 (0.021)	0.277 (0.414)	0.243*** (4.167)	0.160** (2.545)	1.020*** (12.830)
Adjusted R ²	0.604	0.746	0.484	0.905	0.909	0.909
Number of observations	186	60	126	248	80	168

The numbers in parentheses are t-statistics. The before-enactment estimator is a fixed effects estimator; the after-enactment estimator is a fixed effects generalized least squares estimator. The “Dirty” industries include the pulp and paper, the chemical, the petrochemical, and the primary metal sectors. The “Clean” industries include all other industries.

NA Not Applicable
 *** Significant at 1%
 ** Significant at 5%
 * Significant at 10%

ENDNOTES

¹ Smart (1992) provides numerous anecdotes of over-compliance by firms with environmental regulations, for example, Dow's promises to reduce its hazardous and non-hazardous emissions to air and water by 90 percent by the year 2000 and to strive for zero emissions as technically possible after 2000 through its 3P+ Program. Note that this anecdotal evidence runs contrary to much of the investment-under-uncertainty literature (Cukierman 1980; Bernanke 1983; McDonald and Siegel 1986; Majd and Pindyck 1987; Dixit and Pindyck 1994), which concludes that an economic agent should refrain from engaging in an irreversible action such as investing when facing an uncertain future. The environmental preservation literature (Arrow and Fisher 1974; Fisher and Krutilla 1974) also concludes that uncertainty will decrease the tendency of a firm to take an action.

² However, see Lurie (1987) and Teisberg (1993).

³ As discussed later, work in the economics-of-crime literature (Becker 1968) is obviously relevant here.

⁴ An important constituency for Byrd was the West Virginia coal mining industry. Dingell represented the Detroit area with its automobile interests, and he also chaired the House Energy and Commerce Committee.

⁵ This new-found optimism was expressed by Representative Henry Waxman (D-California) during a 1989 hearing before the House Subcommittee on Health and the Environment: "We approach these issues today in a very different climate than that which has pervaded clean air legislative efforts in recent years...I am confident that we will see Clean Air Act Amendments enacted this year, and I plan to do all I can to see that strong legislation is moved through the

Congress as quickly as possible” (Hearing before the Subcommittee on Health and the Environment 1989).

⁶ A “nonattainment” area is an Air Quality Control Region violating the National Ambient Air Quality Standards (NAAQS), and “nonattainment area regulation” is intended to resolve any conflict between the NAAQS and growth targets in a region. See Eizenstat and Garrett (1984) for an overview of the CAAA enforcement provisions.

⁷ The Clean Air Act Amendments of 1990 also contain provisions that extend the deadlines for attainment for sulfur dioxide, nitrogen dioxide, and lead.

⁸ For ozone, nonattainment regions are divided into marginal, moderate, serious, severe, and extreme areas; for both carbon monoxide and for particulates, regions are classified as moderate and serious areas.

⁹ Penalties for noncompliance with the CAAA fall into three categories: administrative, civil, and criminal procedures. The purposes of administrative procedures are to deter noncompliant behavior and to recover any economic benefits obtained from noncompliance. Civil actions are called for when these administrative procedures fail. Criminal fines and imprisonment are authorized for knowing violations of such things as a state implementation plan, an administrative compliance order, or a performance standard; fines and penalties are also imposed when a person knowingly makes a false statement, representation, or certification in any application, report, or document. Any source convicted of criminal charges cannot receive any federal government contracts.

¹⁰ By assuming both time-to-build and a convex investment cost function, we incorporate the two main approaches to represent costs of adjusting the capital stock (Dixit and Pindyck 1994).

¹¹ This model focuses upon only upon the issue of whether legislation is or is not enacted. There is also the issue of what specific provisions are included in any legislation that is actually passed. It is straightforward to introduce this latter form of uncertainty, and the conclusions are qualitatively unaffected.

¹² In addition, the optimization indicates that the firm chooses output in each period such that the marginal cost of production (including the expected fine from emissions) equals the marginal benefit of production.

¹³ It is of some interest that sufficiently high levels of the fine can actually reduce firm investment in equipment. A change in the fine rate has two effects on investment, one that operates through the deterrent effect of the fine and also one that operates through its impact on the optimal level of firm output. At “low” levels of the fine rate, investment will increase with an increase in the fine via the deterrent effect of a greater fine. However, above some “critical” level of the fine, further rate increases may reduce investment, since a higher fine rate will reduce optimal firm output and the negative impact on investment from a lower level of output may eventually outweigh the positive impact on investment from deterrence. See Polinsky and Shavell (1979) for a similar result in the economics-of-crime literature.

¹⁴ PACE information is not without some limitations. Levinson (1996) notes that the respondents to the PACE survey are asked to provide direct dollar amounts spent on pollution abatement, and it may be impossible for these respondents to assess the true economic costs of pollution abatement, including inefficiencies resulting from input substitution or altered production processes. See Jaffe, et al. (1995) for a further critique of the PACE data. The use of the reported capital expenditures appears to be the least controversial of the reported measures of pollution abatement activities. However, Gray and Shadbegian (1998) note that the firms

completing the PACE survey changed over time, making a firm-level panel data difficult to construct.

¹⁵ There is an even more marked skewness at the industry level. Mean industry investment before enactment is \$25.0 million versus median industry investment of \$6.8 investment; after enactment, mean (median) industry investment is \$58.3 million (\$8.6 million).

¹⁶ In “markup” meetings, legislation that may be reported to the parent committee or to the Congress is considered (Deering and Smith 1997).

¹⁷ The data source for the Agendas Project Hearing Data is the Congressional Information Service/Annual: Abstracts of Congressional Publications and Legislative History Citations. This data set contains information on the number of hearings, the length of hearings (days and sessions), the topic of the hearings, and the committees, subcommittees, panels, and commissions involved in the hearing.

¹⁸ Given that many industries did not pay any fine, the number one is added to the average fine when transforming *Fines* via its natural log.

¹⁹ The depreciation rate is calculated by dividing total depreciation by the total capital stock.

²⁰ There may be some consistency problems in combining PACE, AIRS, and CompuStat data. PACE and AIRS data do not distinguish between publicly traded firms and non-publicly traded firms, whereas CompuStat data do.

²¹ Note that there are significantly more than 62 industries in the PACE data set. The 62 industry observations in each year remain after merging the various data sets.

²² A fixed-effects model is appropriate when analyzing a specific set of industries (Baltagi 1995; Greene 1993, Judge et al. 1985). The major drawback of a fixed-effects model is lost degrees of freedom due to the large number of dummy variables that need to be estimated. The Hausman

test statistic of 74.3 with the corresponding p-value of 0.00 strongly rejects a null hypothesis of a random-effects model. It is important to note that, while the industry-specific intercept estimates will be inconsistent, the slope coefficient estimates are consistent but not efficient when the number of cross-sectional observations is large and the time period is fixed (Baltagi 1995). Due to the inclusion of the lagged dependent variable through the capital stock, this estimator may suffer from small sample bias even in the absence of serial correlation; however, this estimator is consistent as the time period approaches infinity (Baltagi 1995).

²³ In fact, the problem of heteroskedasticity is not present in our fixed effects estimates. The LM heteroskedasticity test statistic for the fixed effects estimates for all industries before the enactment of the CAAA is 0.46 with the corresponding p-value of 0.50; after enactment of the CAAA, the statistic is 0.04 with a p-value of 0.84.

²⁴ This Durbin-Watson statistic is meaningful because data have been adjusted for the use in panel data estimation, following the suggestion of Bhargava, Franzini and Narendranathan (1982). See Baltagi (1995) for discussion.

²⁵ A Chow test was performed to test for differences between the before-CAAA and after-CAAA estimates. For all industries, the F-statistic was 2.32, which is greater than the critical F-statistic of 1.00 at the one percent level and which thereby leads to the rejection of the null hypothesis that the estimates are the same.

²⁶ All estimation results are available upon request.

²⁷ When we enter all variables linearly, including *Investment*, the impact of *Subcommittee Preferences* remains positive and significant, although the level of significance declines. For example, the estimated coefficient (t-statistic) for *Subcommittee Preferences* is 0.028 (1.662),

0.243 (1.147), and 0.037 (1.660) for all industries, “dirty” industries, and “clean” industries, respectively.

²⁸ As was the case with *Subcommittee Preferences*, the impact of *Subcommittee Activities* remains negative when all variables are entered linearly. However, the impact is never statistically significant.

²⁹ These results are largely unchanged for the linear specifications, although the significance levels of the coefficient estimates are always lower in the linear specifications.

³⁰ For example, in a different though related domain, there is some evidence that the Internal Revenue Service has apparently chosen to keep its enforcement procedures hidden from taxpayers, in the belief that such uncertainty is able to generate higher compliance levels by firms and individuals. See Alm, Jackson, and McKee (1992).