ENVIRONMENTAL REGULATION AND LABOR DEMAND: EVIDENCE FROM THE SOUTH COAST AIR BASIN

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ABSTRACT

The devolved nature of environmental regulation provides an excellent opportunity for estimating the effects of regulation on employment, by generating rich variation in regulation across regions and over time. We exploit this variation using direct measures of regulation and plant data. We estimate the employment effects of an unprecedented increase in air quality regulation in the Los Angeles region, using unregulated plants in other regions, industries and years for comparison. While environmental regulation is generally thought to reduce employment, economic theory is ambiguous on this point, since pollution abatement technologies may be labor using. We find that air quality regulation induced very expensive investments in abatement capital for individual plants, especially for oil refineries. Despite these high costs *we find no evidence that environmental regulation decreased labor demand, even when allowing for induced plant exit and dissuaded plant entry.* If anything, air quality regulation probably increased employment slightly.

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1. Introduction

The past 25 years have witnessed a dramatic increase in environmental regulation as the public has become increasingly sensitive to environmental quality. The large and increasing cost of that regulation[1] has fueled a debate over its cost-effectiveness in improving environmental quality. The recent *increase* in stringency of national ambient air quality standards has amplified that debate. Chief among the perceived costs of regulation is the loss of employment. The issue of job loss often looms over policy debates about new regulation to protect the environment.[2] The fear that regions would "race to the bottom" in setting lax environmental regulations to avoid local job loss was one reason for the establishment of the U.S. Environmental Protection Agency (EPA). In light of these concerns, efficient regulation requires precise estimates of its effects on employment.

Of course, environmental regulation does not necessarily reduce labor demand. While abatement probably increases marginal costs and decreases labor demand through decreased sales, abatement activity may also complement labor, causing increased labor demand. Thus theory gives an ambiguous prediction of the employment effects of environmental regulation.[3] Empirical studies have also yielded mixed results on these employment effects (Jaffe et at, 1995).

Estimating the effects of environmental regulation is difficult for a number of reasons. Some studies have estimated the effects of regulation by regressing outcomes on measured abatement activity (for example, Gray and Shadbegian (1993)). This approach is confounded by selection bias and measurement error. Plants that can abate pollution at low cost probably have the smallest employment effects and are most likely to abate voluntarily. Thus these plants will bias estimates of the effects of *induced* abatement on employment, making abatement appear less costly than it is. Measurement error in abatement costs is likely to bias estimated effects toward zero.

Our solution to these estimation problems is to gather extremely rich data that allow construction of relevant comparison groups for each industry affected by local air quality regulations. These comparison groups represent the counterfactual case in which manufacturing plants are not subject to the same regulation.

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1 American manufacturing plants invested \$4.3B in 1994 to abate air pollution (4% of capital investment) and incurred another \$6.1B in air pollution abatement operating costs (Census Bureau, 1996). The cost of abatement for the U.S. economy is estimated by the EPA at 2.1% of GDP for 1990 (Jaffe et al, 1995).

2 For example, in California, employment effects must be taken into account in the formulation of environmental regulations (Sept. 1994, resolution 94-36, South Coast Air Quality Management District).

3 Regulations generally either set emission standards or mandate emissions control equipment.

We code the regulations as binary variables and estimate the effect of regulation on employment directly (rather than the effect of abatement on employment).

The richness of our data comes from the devolved structure of U.S. environmental regulation. Since the EPA delegates much of the regulatory authority to state and local agencies, regulatory stringency varies across regions for the same industries. The nature of regulation in manufacturing provides variation across industries in the same region and over time. It's worth stressing that although the bulk of air quality regulation is local, this is the first study we know of that directly estimates the effects of these regulations using a quantitative approach that includes comparison plants. To implement this approach we developed a method of translating complex technical regulations into meaningful, quantitative measures. The principal methodological contribution of this paper is the development of a coding procedure that avoids bias due to "data mining" using a method we call "sequestering the data."

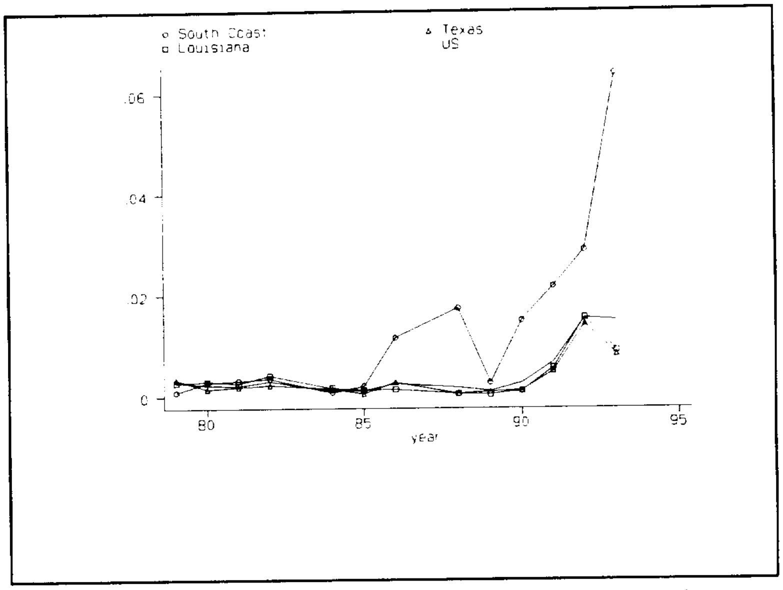

Figure I: Abatement Investment/Value of Shipments in Refineries
Source: PACE Survey

Los Angeles provides our study with an episode of sharp increase in air quality regulation in the 1980s. The South Coast Air Quality Management District (SCAQMD), which regulates the air basin containing Los Angeles and her suburbs,[4] enacted some of the country's most stringent air quality regulations between 1979 and 1991. These regulations were triggered by the unique climate and geography of the South Coast which trap air pollutants in a thermal inversion near ground level, leaving the South Coast with some of the nation's worst air quality. In the late 1970s the SCAQMD found itself far out of compliance with EPA ambient air quality standards. The South Coast responded by instituting a set of extremely stringent regulations in an attempt to meet those standards. For example, Figure I illustrates the costs imposed by these regulations on South Coast oil refineries. South Coast manufacturing plants faced much faster increases in

[4] The South Coast Air Basin consists of Los Angeles, Orange, Riverside, and the non-desert portion of San Bernardino Counties.

abatement costs than comparable plants in Texas and Louisiana, regions essentially free of local air quality regulation. These very strict and often innovative approaches to environmental regulation have often been copied by other regions in their attempts to comply with increasingly stringent air quality standards. Since the same imitation may result from the increased stringency of the July 1997 EPA air quality standards, a study of the employment effects of these South Coast regulations is particularly relevant for local regulators in other regions.

We exploit those three dimensions of variation, across regions, industries and time, to estimate the effects of air quality regulation on labor demand, constructing a sample including both plants in the South Coast subject to changes in regulation and plants in the same industries in other regions of the U.S. that underwent no such change. To match the degree of detail in regulatory variation we use two panels of plant level data made available to us by special arrangement with the Census Bureau: the Pollution Abatement Costs and Expenditures Survey (PACE) in 1979-91 and the Census of Manufactures in 1977, 82, 87 and 92. These data allow us to identify plants subject to new South Coast regulations and to compare them with plants (plant-years to be precise) not subject to new regulations. Using this approach we can remove potentially confounding plant effects, and industry and/or region specific shifts in employment in estimating the effect of regulatory change on employment. In analysis of the Los Angeles area over the 1980s these are key issues, as the regional concentration of declining defense industries created a secular decline in employment which has been falsely attributed to environmental regulation. We claim that the incidence of regulation is orthogonal to sample selection because the timing of regulation was due to the confluence of increased stringency of federal (EPA) air quality standards and the serious air quality problem in Los Angeles. The data are rich enough to allow construction of various comparison groups in order to test the robustness of our results.

We find that while regulations impose large costs they hardly affect employment. Compliance with a new regulation induces \$0.5M of abatement investment per plant (with a standard error of \$0.2M). Increases in stringency of a regulation induces \$1.8M (\$1.0M) of abatement investment. The employment effect of compliance is 2.2 (1.4) workers per plant while that of increased stringency is -2.6 (4.2) workers. The cumulative predicted effect of 14 years of air quality regulation is 8500 jobs created, with a 95% confidence interval that ranges from -6500 to 23,500. These are very small effects in a region with 14 million residents. While not statistically distinct from zero, the key finding is that the large negative employment effects alluded to in public debate can clearly be ruled out.

Small employment effects are probably due to a combination of three factors: a) regulations apply disproportionately to capital intensive plants with very little employment; b) these plants sell to local markets where competitors are subject to the same regulations, so regulations do not decrease sales very much; and c) abatement inputs complement employment. These estimated employment effects include the effect of induced plant exit and entry.

The paper proceeds as follows. Section 2 provides background about environmental regulation in the SCAQMD. Section 3 reviews the literature on the effects of environmental regulation on labor markets. In Section 4 we derive estimating equations from a model of labor demand under regulation. Section 5 describes our data. In Section 6 we present results and Section 7 concludes.

2. Background: The Regulation of Air Quality

Federal environmental regulation in the United States began in 1970 with the establishment of the U.S. Environmental Protection Agency (EPA). Before then regulation of environmental quality fell under state and local jurisdiction. Few states or locales had environmental policies that consisted of much more than nuisance-type laws. Since environmental regulation imposes costs on firms there was concern that states would "race to the bottom". That is, each state would be reluctant to enact stringent environmental regulation for fear of losing business, so they may compete for employment by enacting looser regulations than their neighbors.

The EPA was established in part to prevent this race by setting national standards for environmental quality -- standards based on health criteria alone, not on economic cost-benefit analyses. For air pollution, these standards are known as the national ambient air quality standards (NAAQS) and apply to six "criteria" air pollutants (sulfurous oxides, nitrous oxides, particulate matter, volatile organic compounds, ozone, and airborne lead). The EPA is responsible for developing uniform national standards for environmental quality. States are responsible for developing state implementation plans (SIPs) which must be approved by the EPA. The plan indicates how the state will ensure that all its regions attain the standards. The EPA can withhold federal monies from states that do not submit SIPs that meet federal approval and has the authority to take over environmental regulation if a state does not attain the national standards.

In general, federal environmental regulations are limited to new sources of pollution (New Source Performance Standards "NSPS"), except in regions that are out of compliance with federal standards or are deemed "pristine" (Prevention of Significant Deterioration regions, "PSD"). States are responsible for regulating existing stationary sources of pollution, as well as mobile sources. Thus, most regulation is at the state and local level.

Within California, mobile sources are regulated by the California Air Resource Board (CARB), while the regulation of stationary sources is delegated to the 34 air quality management districts (AQMD).

The South Coast Air Quality Management District (SCAQMD) is responsible for the South Coast Air Basin in the area around Los Angeles.[5] The SCAQMD is further out of compliance with the NAAQS for criteria air pollutants than any other large region, which explains the unprecedented severity of regulations enacted over the 1980s.

Severe air pollution in the Basin is partly attributable to prevailing weather patterns. The Basin is an arid region with little rain or wind, abundant sunshine, and poor natural ventilation -- conditions that exacerbate air pollution, especially the formation of ozone. Furthermore, it is an area of high industrial output and associated population growth. In 1990, the Basin accounted for 4% of the population of the United States and 47% of the population of California.

When national ambient air quality standards were first established, the Basin was out of compliance with four of the six criteria pollutants (SOx, NOx, lead, PM, O_3 and CO). Since then, the Basin has significantly improved ambient air quality through stringent regulation. Between 1976 and 1993 the Basin reduced out-of-compliance days by 47%, from 279 to 147. Table I illustrates the associated increase in abatement costs. Between 1979 and 1991 South Coast manufacturing plants increased annual air pollution abatement costs by 138%, nearly twice the national rate of increase and increased air pollution abatement investment by 127%, ten times the national rate of increase. Despite this effort the South Coast remained out of compliance with three of the six federal ambient air quality standards (PM_{10}, O_3, CO) in 1993, and had the highest annual average of PM_{10} and NOx in the nation.

Studies suggest that South Coast air quality endangers health and damages the quality of life. Hall et al (1989) reported that noncompliance with federal standards in the 1984-86 period increased the death rate by one in ten thousand (a risk that doubles in San Bernardino and Riverside Counties).[6] Also, over half the Basin's population experienced a Stage 1 ozone alert annually, during which children were not allowed to play outdoors, and the average resident suffered 16 days of minor eye irritations and one day on which normal activities were substantially restricted.

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5 In 1947, long before the advent of Federal regulation of ambient air quality, Los Angeles County formed California's first Air Pollution Control District (APCD) to develop abatement policy. In 1977, Orange, Riverside, and the non desert portion of San Bernardino Counties joined Los Angeles County to form the SCAQMD.

6 For comparison, the risk of death from an automobile accident in California is 2/10,000.

3. The Literature

Though most environmental regulation is local, this is the first study we know of that directly estimates the effects of local air quality regulations using a quantitative approach that includes comparison plants. A number of empirical studies have investigated the effect of federal regulation on employment and other economic outcomes. Gray (1987), and Bartel and Thomas (1987) study the effects of the Occupational Safety and Health Act (OSHA) and EPA. Gray studies the relationship between enforcement and compliance for EPA and OSHA, finding that compliance is higher for industries with high profits, high wages, low compliance costs, and frequent inspections. Bartel and Thomas estimate the effect of EPA and OSHA on both wages and profits and find *regional* differences in the impact of regulation. Gray (1987), and Gray and Shadbegian (1993a) also find that manufacturing plants with high abatement costs have lower productivity. Gray and Shadbegian (1993b) find that manufacturing plants with high abatement costs have high labor demand.

Other studies attempt to measure the effect of a particular set of environmental regulation on a *specific* industry. For example, Hartman et al (1979) on the U.S. copper industry find that federal environmental regulation reduces labor demand. Gollop and Roberts (1983) study electric power plants, finding that federal environmental regulation reduces productivity.

This paper is similar in spirit to investigations of how plant location responds to differences in local environmental regulations. Henderson (1996) uses as a proxy for local regulatory activity an indicator for whether a county attains compliance with federal ground level ozone standards. He finds that transition into attainment is associated with an incursion of polluting plants. Gray (1997) finds that states with more stringent enforcement have fewer plant openings. Levinson (1996) examines plants in pollution intensive industries and finds little impact of environmental regulation on the location of new manufacturing plants (1982-1987).

This work is also related to a recent literature in labor economics and public finance that uses cross-sectional variation in changes in regulations, laws and institutions to study the effects of these changes. The variation is often arguably exogenous and the results are of interest to policy makers contemplating similar regulatory changes. Meyer (1995) provides a survey. This study offers an innovation to that strand of the literature by demonstrating that useful regulatory variation can come from a set of diverse, technical regulations once they are appropriately quantified.

4. Labor Demand Under Environmental Regulation

In this section we motivate our estimating equations with a model of labor demand that allows regulation to act through two separate mechanisms, the output elasticity of labor demand, and the marginal rates of technical substitution between abatement activity and labor. The partial static equilibrium model of production (Brown and Christensen (1981)) allows for the levels of some "quasi-fixed" factors to be fixed by exogenous constraints, rather than by cost minimization alone. We apply that approach, treating costs incurred to comply with environmental regulation -- pollution abatement capital investment and abatement costs (labor, materials and services) -- as "quasi-fixed". Labor, materials and productive (regular) capital are the variable factors.

Assume a cost-minimizing firm operating in perfectly competitive markets for inputs and output. There are L variable inputs and M "quasi-fixed" inputs. The variable cost function has the form:

(1) $$CV = H(Y, P_1, \ldots, P_L, Z_1, \ldots, Z_M)$$

where Y is output, the P_l are prices of variable inputs, and Z_m are quantities of quasi-fixed inputs.

Profit maximization implies a set of first order condition that will yield demands for the variable inputs X_j that are functions of prices, output, and quantities of the other inputs, which we approximate by the linear equation.[7]

(2) $$X_j = \alpha_j + \rho_{Y_j} Y + \sum_{k=1}^{L} \gamma_{jk} P_k + \sum_{k=1}^{M} \beta_{jk} Z_k, \quad j = 1, \ldots, L.$$

The reduced form effect of regulation (R) on demand for a variable input (X) (such as labor) can be written:

(3) $$X_j = \delta_j + \mu_j R.$$

The effects of regulation on employment are through the mechanism:

(4) $$\frac{dX_j}{dR} = \rho_{Y_j} \frac{dY}{dR} + \sum_{k=1}^{M} \beta_{jk} \frac{dZ_k}{dR} + \sum_{k=1}^{L} \gamma_{jk} \frac{dP_k}{dR} = \mu_j.$$

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[7] We are restricted to a linear approximation by data constraints. For pollution abatement capital we have only first differences (investment), not levels.

If input markets are large and competitive, regulatory change will have no effect on input prices so the final term in (4) will disappear,[8] leaving the first two terms. The first term reflects the effect of regulation on demand for variable factors through its effect on output. This output effect of environmental regulation is widely believed to be negative (though economic theory gives no clear prediction: if compliance is achieved through an investment that reduces marginal costs, dY/dR could be positive). The second term reflects the impact of regulation on demand for variable factors through its effect on demand for the quasi-fixed abatement activities, Z, and the marginal rates of technical substitution between abatement and variable factors. The change in demand for quasi-fixed factors due to an increase in regulation, dZ/dR, must be positive. The sign of β_{jk}, which reflects whether abatement activity and labor are complements is not known *a priori*. PACE fall into two general categories, the first of which -- "end-of-pipe" technologies such as scrubbers and precipitators -- remove pollutants from *existing* discharge streams before their release into the environment. The second consists of investments that alter the underlying production *process*, such as the installation of new boilers that are designed to operate more efficiently and at lower levels of emissions. The first method probably complements labor, particularly production workers. The second often reduces demand for production workers due to the skill-bias of technological change. Our estimates will reflect the average of these effects.

Some of the employment effects of regulation may be through induced exit of plants, as output is reduced to zero, and dissuaded entry (Gray (1995), Henderson (1996), Levinson (1996)). For those effects only the output effect (the first term of (4)) is relevant. We will present below estimated employment effects which include effects through entry and exit.

Evidence of the effect of regulation on output *(Y)* and abatement *(Z)* will help us interpret the estimated effects of regulation on employment in (3). Ideally, we would like to estimate the parameters of (4) using regulatory change variables as instruments for *Y* (value added) and *Z* (the quasi-fixed factors). This will prove to be too ambitious a demand to make of our data. The effect of regulation on abatement and output is estimated by

(5) $$Z_k = a_k + b_k R,$$

and

(6) $$Y = a_Y + b_Y R.$$

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[8] This assumption can be tested with data on input prices. We haven't attempted it yet. If the assumption fails there are simply more parameters to be estimated, reflecting the pervasiveness of regulation and the elasticity of labor supply.

We turn now to a description of the data, and an explanation of how the regulatory indicator R is constructed.

5. Data Description

We can fully exploit variation in regulation across industries, regions and time by using data at the plant level. We use two (unbalanced) panels, both drawn from Census Bureau data: The Survey of Pollution Abatement and Control Expenditures (PACE) is linked to the Annual Survey of Manufactures (ASM); and the Census of Manufactures (COM). (Plant records from the ASM linked over time are the basis of the Longitudinal Research Database (LRD) panel compiled by the Center for Economic Studies of the Census Bureau).

The Annual Survey of Manufactures samples the population of manufacturing plants, including large plants (250 or more employees) with certainty. Smaller plants are rotated out of the sample at five year intervals. From these data we use the employment, value added, and capital investment variables. PACE reports abatement investment and operating costs by the medium abated (air, water, and hazardous waste). We use air pollution abatement costs and investments.

To include the possibility of entry and exit in our analysis we use the Census of Manufactures, which is a complete enumeration of manufacturing plants conducted every five years. A plant is a physical location engaged in a specific line of business. Plants with 20 or more employees are generally required to submit a survey form to the Census, while smaller plants are often enumerated using payroll and sales information from the Social Security Administration and the Internal Revenue Service.[9] From these data we use the employment, value added, and capital investment variables.

Our most difficult task in this project was to construct measures of regulatory change. To date there is no comprehensive database on environmental regulations at any level other than the Federal. Data on state and local regulations must be compiled from a variety of sources. California State environmental regulations as a whole are the responsibility of the California EPA, while the SCAQMD is responsible for determining regulations specifically for the South Coast Air Basin. From these sources we constructed a data set for the Basin detailing *all* changes in environmental regulation affecting manufacturing plants in 1979-91. We identified 37 separate regulations, many affecting more than one industry and tracked their adoption dates, compliance dates, dates of increases in stringency as well as the pollutant involved and the method of

[9] Imputed plants account for approximately 2.2% of value added, [Bureau of the Census (1991)].

compliance. We used the regulation books, the SCAQMD library and a series of conversation with the both regulators and regulatees to establish the timing and coverage of regulations. Regulations were matched to industries using the text of the regulation, our understanding of production technologies and the opinions of the regulators in the SCAQMD For the comparison regions of Louisiana and Texas we established that no comparable local regulations exist.

One important innovation is developing a method of coding highly technical regulatory data without biasing the results. The potential for bias arises because the regulations each have enough attributes that their coding involves many subjective judgements. For instance, a regulation requiring capital investment with a compliance date in January will force a plant to invest in the previous year, so it is coded in the previous year. Subjective judgement implies a danger of (inadvertently) "overfitting" the regression or "data mining", by coding the data in a way that will help explain variation in the left hand side variable (in our case, employment). Our solution for overfitting is to sequester the data, not allowing the staff who code the regulations to observe the left hand side variables. We believe that *this method of sequestering the data is crucial to obtain unbiased inferences from microregulatory data.* To achieve precision in coding we interviewed regulators and regulatees both personally and by telephone. In this way we developed an exhaustive coding of significant South Coast regulations for the 1979-1993 period.

Appendix Table A2 lists the industries affected and the adoption and compliance dates (for 1979-93). They are concentrated in heavy industry (paper, chemicals, petrochemicals, glass, cement, steel and transport) but also include some baked goods. The regulatory data were matched to each of the two panels of plants (ASM-PACE and COM). For each plant-year we measure the number of new regulations adopted, new regulations that must be complied with and the number of regulations with increases in stringency. To provide rich comparison groups we include in each panel all manufacturing plants in the U.S. in industries affected by SCAQMD regulations.

6. Estimation

6.1 Econometrics

We are interested in estimating the effect of the South Coast regulations on employment in regulated plants. We first describe the estimating equation and then discuss potential sources of bias and how we deal with them. Equation (3) can be taken to data as:

$$L_{it} = \delta_i + \varphi_t + \mu R_{it} + \eta_{it}, \tag{3'}$$

where μ is the effect of regulation on employment, δ_i is a plant specific fixed effect and φ_t is a year effect for $i = 1,\ldots,N_t$ plants and $t = 1,\ldots,T$ years. We eliminate the plant effect (and any industry or region effect in the level of employment) by differencing to yield

$$\Delta L_{it} = \Delta\varphi_t + \mu\Delta R_{it} + \Delta\eta_{it}. \tag{3''}$$

The parameter μ can be consistently estimated if Cov $(\Delta R_{it}, \Delta\eta_{it}) = 0$.

The assumed orthogonality of regulatory change and unexplained variation in employment change is conditional on year indicators. This conditioning is necessary. Regulatory change is certainly bunched in particular years, which typically have their own secular employment change. In some specifications we include additional separate intercepts in (3") for 35 four digit industries and 50 states to allow industries and states to have their own secular employment changes. We always allow the South Coast region to have its own intercept. The orthogonality assumption is a claim that regulatory changes are correlated with employment changes only through the causal effect μ, once the common effect of time $\Delta\varphi_t$ is accounted for.

The effects of *local* regulatory change on employment are described by μ. It should provide a tool for local policymakers to use in predicting the local employment effects of similar regulatory changes (*e.g.*, tightening standards for airborne pollutants). The effect of a regulation can be interpreted as the marginal effect of imposing the (more stringent) SCAQMD regulations over and above the average level of regulation (Federal, State and local) these industries face in the rest of the country. Of course, a local regulator may choose a different mix of regulations, based on the local distribution of industry or local environmental and labor market conditions. In practice, air quality management districts tend to adopt the more stringent regulations already imposed elsewhere so that South Coast regulations are often copied.

Before turning to results, we discuss four potential sources of bias that are common in this literature and how our identification strategy deals with them.

Selection Bias

This is the first effort we know of to estimate the effects of local air quality regulations directly in an analysis including comparison plants. An alternative approach which indirectly measures these effects is to estimate (2) directly, using abatement activity (Z) as a covariate in a labor demand function. That approach avoids the considerable effort described above of quantifying regulations.

Estimates derived from regression on measured abatement activity are susceptible to selection bias. Plants may carry out PACE voluntarily even in the absence of regulation, a phenomenon that is probably more common at plants that anticipate small disruptions due to PACE (Gray 1987). That would tend to understate negative employment effects of PACE associated with regulation. This has been suggested as an explanation for the Gray and Shadbegian (1993b) result that PACE is positively correlated with employment.

Measurement Error

PACE is often poorly measured, both because the distinction between investments in new capital and pollution abatement capital is often subtle[10] and because the cost of a counterfactual capital investment that would be made in the absence of the need to abate is difficult to imagine after many years of air quality regulation. (For example, new equipment is frequently both more efficient and cleaner.) This is a type of measurement error. In the regression of employment on abatement measurement error will generally bias coefficient estimates towards zero.

Anticipated Regulatory Change

An additional problem that arises in measuring the effects of any regulatory change is that measurement of treatment effects may be frustrated by changes in behavior in anticipation of regulatory change (Meyer 1994). For that purpose we measure not only the compliance date but also the date in which a regulation was introduced into law, which is usually a few years earlier. If plants adjust behavior in anticipation of required compliance with a regulation we would expect to see that adjustment in the adoption year. By including an indicator for that date in the set of regressors we attempt to measure the extent of anticipatory reaction to regulatory change. Engineers and managers interviewed indicated that in the case of environmental regulation this type of reaction is unlikely, as compliance typically involves high costs which their firms would not incur before it is absolutely necessary.

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[10] Jaffe et al (1995).

We describe regulations using three binary indicators for new regulations, one for the year of required compliance. one for the year in which an existing regulation became more stringent and a third on the date of adoption of the regulation into law. The coefficient on the compliance indicator variable is the average effect of compliance, averaged over all South Coast regulations introduced during this period. The coefficient on the increased stringency variable has an analogous interpretation. The date of adoption into law is presented only as a test of the existence of an anticipatory response.

6.2 Results

Descriptive Statistics: ASM-PACE

The ASM-PACE panel has about 1850 plants per year. It contains data for 1979-91, excluding 1983 and 1987.[11]

Table II reports both sample means and means weighted by sampling weights. The 18,522 plant-year observations in the sample represent 60,394 plants in the population. From the weighted (population) means we see that in these industries annual abatement capital investment and operating costs are high, averaging \$104,000 per plant and \$273,000 per plant respectively, representing about 1.5% of value added. Abatement costs vary a lot between plants, with standard errors an order of magnitude larger than the means. This is a reflection of the large costs incurred by a small number of petrochemical and chemical plants. Note that 5.3% of the sample plant-years are located in the L.A. Basin. The compliance indicator averages 0.96%, so that a little less than one percent of the sample (of plant-years) is subject to new compliance regulations. The average year to year change in employment is -10, which reflects the national contraction in manufacturing employment in heavy industry over the 1980s.

Abatement Effects

We begin with a presentation of estimates of equation (5), the effects of regulation on the quasi-fixed factors abatement investment and abatement costs. Table III describes the result of estimating (5) in a panel for net abatement investment. It is estimated in first differences (as in (3")) with year to year changes in

[11] The 1983 plant-level PACE data was declared unusable by the Census Bureau in September 1995 because of poor quality. No PACE survey was performed in 1987.

abatement capital (net abatement investment) on the left hand side and ΔR on the right hand side. The panel includes plants in all industries affected by SCAQMD regulation in the 1979-91 period, with plants in the rest of the U.S. included as comparisons. The results indicate that compliance and increases in regulatory stringency have large and significant effects on abatement investment. The units are thousands of dollars (constant 1991$) so that the coefficient on compliance in column (1) implies $640,000 of capital investment induced by each new regulation. The estimated effect of increased stringency is larger, but less precisely estimated. The point estimates in column (1) indicates that increased stringency induces an additional $2.1m in investment. These results are essentially unchanged by the inclusion of industry and state effects in columns (2) and (3). Those coefficients clearly indicate that the South Coast regulations imposed large costs on manufacturing plants.

The first row indicates no evidence that adoption of regulations into law has any effect on abatement investment. That results is consistent with the opinion of environmental engineers that anticipatory investment was unlikely because the high cost of abatement investment. The right-most column reports estimates allowing separate slopes for oil refineries, implying that the positive aggregate effects of investment are entirely due to multimillion dollar investments by oil refineries (SIC 2911), with the effects for other industries insignificantly different from zero.

Tables IV and V repeat that procedure for abatement operating costs and value added respectively. We find no evidence that regulatory change has any effect on abatement operating costs or value added. The data may be uninformative because differencing the levels of abatement cost and value added exacerbates measurement error. Measurement of abatement operating costs is especially suspect because its variation from year to year seems to be unreasonably high.

The weak results in Tables IV and V preclude using regulatory change as an instrumental variable in estimating the parameters of (2). We turn instead to our main goal, estimation of the reduced form relationship between regulatory changes and employment changes. While this approach cannot reveal the mechanism by which employment is affected by regulation, it can give us estimates of the average treatment effects.

Estimated employment effects in Table VI are generally *positive*, though not statistically distinct from zero. The specification allowing industry and state specific year to year employment changes yields point estimates of an additional 3.1 employees in compliance years and 4.9 employees in years of increased stringency. While these estimates do not rule out zero effects, they do rule out the large negative effects ("job loss") often attributed to environmental regulation in the popular press.

As before, there is no evidence that adoption dates matter.

The coefficients on compliance and increased stringency dates can be used to estimate the cumulatative effect of environmental regulation on manufacturing plants in the South Coast. The point estimate is an increase of 2260 employees with a 95% confidence interval of [-2317, 6837]. Using the lower bound of that confidence interval as a worst case, job loss due to regulation was most probably less than 2317 employees. In an area with 14 million people that's a very small effect, a number of the same order of magnitude as the reported annual rate of excess deaths associated with being out of compliance with national standards.

Taken together, the results in Tables III and VI provide an interesting contrast. Though air quality regulation induces very large investments in abatement capital in oil refineries, it has no discernible effect on value added and seems to have no negative effect on employment in refineries or in any other industry. While it may not be surprising that manufacturing plants with no discernible costs associated with regulation show no employment effects, it does stand in contrast to complaints of business groups, mostly outside of oil refining, that environmental regulation "costs jobs". In fact, the table suggests that these regulations may increase employment slightly.

Equation (4) provides a likely explanation for these results: complementarity between pollution abatement capital and labor in production dominated small output effects of regulation to provide a net positive effect of air quality regulation on labor demand.

How robust is the finding of small positive employment effects to different choices of comparison groups? Table VII investigates alternatives. In the left column the comparison group is the same South Coast plants in the years in which new regulations are not introduced. In the middle column the comparison group includes both South Coast plants in other years and plants in the same industries in Texas and Louisiana. These two states are essentially free of local environmental regulation over this entire period, so they provide a clean comparison group. The right column reports the result of including plants in the same industries in the entire US in the comparison group, as in Table VI. The results are essentially identical. There are very small positive employment effects associated with compliance dates and small, generally positive effects of increased stringency dates, no matter which plants outside or inside the South Coast are used for comparison.

Entry and Exit Analysis

Environmental regulation may influence employment by inducing plants to exit or dissuading them from entering into production. An important limitation of the analysis so far is that entry and exit are not recorded in a panel of continuing plants so that potential employment effects of regulation have gone unmeasured. Cost-minimizing behavior is unambiguous about induced entry and exit. The effects of new regulation on employment through entry and exit must be negative for the regulated industry, as there is no technical complementarity without production.[12]

To capture the effects of regulation through exit and dissuaded entry we turn to the Census of Manufactures. The Census is a quintennial enumeration of all manufacturing plants, numbering between 300 and 400 thousand. These are the most complete data on manufacturing employment available from any source. As before, our subpopulation includes plants which would have been subject to South Coast regulations had they been located in the South Coast.

One weakness of the Census to Census comparison is that over a five year period other events may occur in regulated industries in the LA Basin or elsewhere that confound analysis of the effects of regulation. One such event is the sharp decrease in orders for defense-related goods as the federal government reduced spending on "Star Wars" and other programs. This led to considerable job loss in the aerospace industry of Southern California, an industry that was subject to two relatively minor environmental regulations in the 1987-92 period.

Aerospace and shipbuilding are closely tied to defense department contracts. About three-quarters of all Defense Department contracts in manufacturing are accounted for by these industries.[13] The top line in Figure II tracks aerospace and shipbuilding employment in the entire U.S. The lower line represents employment in the same industries in the South Coast region. Employment decreased by one half in South Coast aerospace and shipbuilding over just three years in 1990-93. That job loss parallels a sharp national decrease over the same period, most of which was in regions that did not impose new environmental regulations on these industries during this period.

Could some of the decrease in aerospace employment in the South Coast have been due to environmental regulation? It's possible, but the impact was probably small. Most of these industries were affected by only one regulation concerning coatings, which had a compliance date of January, 1993, long after

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12 Regulation could induce entry of plants which produce abatement producing equipment. None of the industries covered by these regulations fall into that category.

13 Calculated from 1992 Census of Manufactures: Manufacturers' Shipments to the Federal Government, Bureau of the Census, June 1996. Standard Industrial (SIC) Codes 3721, 3724, 3728, 3761, 3764, 3769 and 3731.

the sharp downturn in employment.[14] In any case, Figure II illustrates the importance of using comparison plants from other regions in analyzing the effect of a regulatory change. To control for fluctuations in defense procurement we have constructed the sub-population of the Census of Manufactures to exclude the aerospace and shipbuilding industries.

Recall that the reason for using the Census data was that we wanted to account for exit and entry. The Annual Survey of Manufacturers changes its sample of smaller plants periodically so that entry and exit are not well observed and are easily confused with plants joining and leaving the sample. With Census data we observe all plants. The effect of changes in regulation on changes in employment (equation (2)) can be estimated for departing and entering plants as follows: plants entering are assigned zero employment in the census year before they appear and plants departing are assigned zero employment in the census year after they exit. Employment levels are then used to calculate five year differences for all plants.

Table VIII reports 3 periods of 5 year changes in employment: 1977-82, 1982-87 and 1987-92. Average employment change for a plant over these 5 year periods was -1.3 employees, including employment increases for entrants and decreases for exits. Regulatory change is also added up for the five year intervals between Census years. Plants in Texas and Louisiana are assigned no increase in regulations over the five year intervals. Plants in the South Coast had between zero and five new compliance dates for regulations. The average for all plants was 0.25 new compliance dates and 0.05 dates of increased stringency.

It's worth stressing that Texas and Louisiana have been chosen because they have a pollution intensive industrial mix, with large petroleum refining and heavy industry sectors. Unlike the South Coast, Texas and Louisiana benefit from topological and climactic conditions that make them much less prone to accumulate ground level ozone and are essentially free of local air quality regulation. This is key to our analysis. To evaluate the effects of regulation on a plant in the South Coast we want to be able to identify similar plants in regions free of local regulation to represent the counterfactual.

We report in Table IX estimates of equation (3") which allow for exit and entry. The first column reports results including all (non defense) plants, including entrants and exitors. Employment increases by 2.2 persons for each new compliance regulation and decreases by 2.6 for each new increase in stringency. These coefficient estimates are statistically indistinguishable from the estimates based on annual employment and regulatory change reported in Tables VI and VII above, providing corroboration of those results in a

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[14] Shipbuilding was affected by two regulations with compliance dates in 1991 and 1992 but it is a relatively small industry. The results below are robust to the treatment of shipbuilding.

different data set, over a longer time period and including exit and entry effects. The similarity of the annual and quintennial results is evidence that these estimated employment effects are not subject to measurement error bias or confounded by lagged or anticipated response. As in the annual data, neither of these figures is statistically distinct from zero, but the standard error is small enough to rule out large employment effects, both positive and negative. The coefficients allow a fairly precise estimate of the cumulative effect on employment of 14 years of air quality regulation in the South Coast: 8500 jobs created, with a 95% confidence interval ranging from -6500 to 23,500 jobs. This is a very small effect in a region with 14 million residents, much smaller than the effect of lost defense contracts illustrated in Figure II. As before, large negative employment effects can certainly be ruled out.

The rest of the table checks the robustness of this basic result to changes in specification and sample. The second column reports a specification including a separate slope for oil refineries, as in Table VI above. This increases the negative coefficient on stringency for non-refineries, but increases the accuracy of estimation. Again, large employment effects for nonrefineries can be ruled out and employment effects for refineries have positive point estimates.

Column 3 shows the effect of ignoring government contracts and including defence-related industries in Figure II. That estimate would imply large negative employment effects. This confusion between the effects of decreased defense contracts and the effects of environmental regulation may be why environmental regulation was implicated for the job loss in South Coast manufacturing. As we argued in the discussion of Figure II above, that is a false inference.

Columns 4 and 5 examine entry and exit explicitly, breaking up the sub-population in column 2 into separate entry/exit and continuing plant sub-populations. Surprisingly, we find coefficients of similar size for exitors and entrants on the one hand and for continuing plants on the other. Note that while there is a large potential for misclassification of continuing plants as entrants and exits in the Census, that misclassification does not bias our estimates. Though the Census includes all plants it is not designed for longitudinal study, so that firm identifiers may change between waves of the Census, leading a continuing plant to be falsely classified as an exitor and an entrant. For example, if a continuing plant has employment decrease from 55 to 50 employees over the 5 years between Censuses employment change should be recorded as -5. If its identification number is changed between Census years it will be misclassified as an exiting plant with 55 employees and another entering plant with 50. We can't think of a reason why this kind of mis-classification would be correlated with regulatory change so we are fairly confident that it does not bias these estimates.

The effects for both entry/exit and continuing plants are small, positive and not statistically distinct from zero. This positive point estimate on compliance is a little surprising (though statistically insignificant) It may be due to misclassification of continuing plants as exit/entry combinations. For completeness we include in the final column the results of estimating the same equation including all nondefense plants in all regions. This sample has the disadvantages of including regions that may have some local air quality regulation and more importantly, may be subject to region - period interactions in employment growth (like the defense contract slowdown in the South Coast). Here the estimated effect of compliance is small and significantly negative and that of increased stringency is small and positive. Since this result is possibly biased we don't think that it offers strong evidence of negative employment effects.

As a whole, these estimates reinforce our conclusion from the annual PACE data reported in Tables VI and VII. Air quality regulation in the South Coast did not cause large scale job loss even when dissuaded entry and exit are taken into account.

7. Concluding Remarks

Air quality regulations introduced in the 1979-92 period in the L.A. Basin did not cost a lot of jobs. They probably increased labor demand very slightly. We reach that conclusion by directly measuring regulations and comparing changes in employment in affected plants to those in comparison plants in the same industries but in regions not subject to the same regulations. Our ability to construct appropriate comparison groups in regions without local regulation is the key to identification of treatment effects.

Reduced form estimates alone are uninformative about why employment effects are so small or why they seem to be positive. Plant visits and a phone survey provide supporting evidence for the explanation suggested by Equation (4) that output effects of regulation are small and abatement complements labor. Most of the managers we spoke to thought that the introduction of abatement technology increased labor demand. While all complained about the nuisance of dealing with regulators and complying with regulations, few complained about lost demand for their product. For the most part we think that this is because these plants sell to local markets and face little competition from unregulated plants (in the oil and chemical industries).

We also find that plants that are induced to respond to environmental regulation only do so at the latest possible moment -- thus adoption dates have little impact on a plant's behavior whereas the mandatory compliance date has a strong impact on behavior. This is not surprising given the magnitude of the capital investment associated with coming into compliance with a given regulation..

Our estimates of positive employment effects contradict the conventional wisdom of employers, so a comment is in order. Beyond posturing in public debate, employers may honestly over-estimate the job loss caused by a pervasive regulation by confusing the firm's product demand curve with that of the industry. The former is more price elastic due to competition from other firms. If all firms in the industry are faced with the *same* cost-increasing regulatory change and product demand is inelastic, the output of individual firms may be only slightly reduced. In that case, the negative effect on employment through the output elasticity of labor demand may well be dominated by a positive effect through the marginal rate of technical substitution between PACE and labor, leading to a net increases in employment as a result of regulation.

In future work we plan to push this estimation strategy to its logical conclusion, the instrumental variable estimation of a structural labor demand equation (the second stage). To do so we require more data. We are currently adding other regions of California to our regulatory data in order to achieve the necessary precision.

Though the public debate has centered around employment effects, a full accounting of costs of regulation should properly focus on the effects of regulation on productivity. We are currently investigating that question. A symmetric analysis of the benefits of the South Coast regulations in improved air quality and health outcomes of residents would allow a complete economic evaluation of this important and unprecedented episode in air quality regulation.

Table I:

Air Pollution Abatement Control Expenditures

(Millions of 1991 Dollars)

	Capital Expenditures		Operating Cost	
	South Coast	US	South Coast	US
1979	101	3313	125	2820
1991	229	3703	298	4978
1979-1991 Growth	127%	12%	138%	77%

Source: Author's calculations from PACE data.

Figures are slightly smaller than published totals for U.S. Manufacturing.

Table II:
Means and Standard Deviations

Variable	Mean	Weighted Mean	Weighted Std. Dev.
Air Pollution Abatement:			
Capital Investment:			
Net*	330	104	1877
Gross*	444	142	1927
Process*	137	43	1110
End of Line*	308	99	1412
Operating and Maintenance Costs*	845	273	2763
Change*	3	0.4	1399
Regulatory Change:			
Compliance (%)	1.27	0.96	12.3
Adoption (%)	0.72	0.75	9.1
Increased Stringency (%)	0.12	0.15	4.3
Value Added:*	72860	25689	100584
Change*	-1785	-600	50584
Employment:	681	267	868
Change	-26	-10	173
L.A. Basin (%)		5.3	22.4

18,522 observations from LRD-PACE, representing 60,394 plant-years in the population of manufacturing plants.

* thousands of 1991 dollars deflated by PPI.

Table III

The Effect of Regulation on
Air Pollution Abatement Investment

	1	2	3	4
Adoption	-65 (218)	-144 (184)	-149 (184)	-11 (55)
(x Oil)	-	-	-	413 (571)
Compliance	640 (243)	525 (228)	528 (227)	-33 (39)
(x Oil)	-	-	-	2745 (1048)
Increased Stringency	2144 (1071)	1795 (1037)	1803 (1034)	-248 (146)
(x Oil)	-	-	-	7006 (2929)
34 industry indicators	-	✓	✓	✓
50 state indicators	-	-	✓	✓
N	18522	18522	18522	18522
R^2	0.011	0.039	0.041	0.058

1. Each estimate includes 9 year indicators and an indicator for the South Coast Air Quality Management District. Standard errors are heteroskedasticity consistent. The mean of net air pollution abatement investment is 104 (1000s of 1991$s).

2. "x Oil" is in each instance a variable set to one if a regulatory change (*e.g.*, adoption) occurred *and* it affected the petroleum industry (SIC code 2911).

Table IV:
Effect of Regulation on Air Abatement Operating and Maintenance Costs

	1	2	3	4
Adoption	-20 (196)	-26 (198)	-27 (198)	-8.2 (17)
(x Oil)	-	-	-	-275 (1330)
Compliance	44 (105)	32 (105)	33 (105)	-0.8 (15)
(x Oil)	-	-	-	309 (610)
Increased Stringency	-621 (644)	-651 (655)	-651 (655)	24 (36)
(x Oil)	-	-	-	-1778 (1481)
34 industry indicators	-	✓	✓	✓
50 state indicators	-	-	✓	✓
N	18522	18522	18522	18522
R^2	0	0.001	0.001	0.002

1. Each estimate includes 9 year indicators and an indicator for the South Coast Air Quality Management District. Standard errors are heteroskedasticity consistent. The mean change in air pollution operating and maintenance costs is 0.4 (1000s of 1991$s). Standard deviation is 1,399.

2. "x Oil" is in each instance a variable set to one if a regulatory change (*e.g.*, adoption) occurred *and* it affected the petroleum industry (SIC code 2911).

Table V:
Effect of Regulation on Value Added

	1	2	3	4
Adoption	-7820 (4416)	-7376 (4231)	-7277 (4232)	-18 (1294)
(x Oil)	-	-	-	-41167 (19691)
Compliance	-3371 (3343)	-1627 (3258)	-1619 (3254)	742 (821)
(x Oil)	-	-	-	-1732 (13801)
Increased Stringency	15100 (15264)	18853 (15855)	18955 (15870)	257 (1558)
(x Oil)	-	-	-	48681 (36439)
34 industry indicators	-	✓	✓	✓
50 state indicators	-	-	✓	✓
N	18522	18522	18522	18522
R^2	0.0064	0.0096	0.0101	0.0114

1. Each estimate includes 9 year indicators and an indicator for the South Coast Air Quality Management District. Standard errors are heteroskedasticity consistent. The mean change in value added is -600 (1000s of 1991$s).

2. "x Oil" is in each instance a variable set to one if a regulatory change (*e.g.*, adoption) occurred *and* it affected the petroleum industry (SIC code 2911).

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Table VI:
Effect of Regulation on Employment

	1	2	3	4
Adoption	2.0 (6.9)	-3.9 (6.8)	-3.2 (6.7)	-4.3 (8.3)
(x Oil)	-	-	-	4.5 (13.3)
Compliance	0.6 (3.3)	3.1 (4.1)	3.1 (4.0)	3.5 (4.8)
(x Oil)	-	-	-	-1.9 (6.6)
Increased Stringency	-8.2 (6.7)	6.0 (12.2)	4.9 (11.8)	3.3 (16.6)
(x Oil)	-	-	-	6.9 (17.0)
34 industry indicators	-	✓	✓	✓
50 state indicators	-	-	✓	✓
N	18522	18522	18522	18522
R^2	0.011	0.023	0.026	0.026

1. Each estimate includes 9 year indicators and an indicator for the South Coast Air Quality Management District. Standard errors are heteroskedasticity consistent. The mean of employment change is -10.

2. "x Oil" is in each instance a variable set to one if a regulatory change (*e.g.*, adoption) occurred *and* it affected the petroleum industry (SIC code 2911).

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Table VII:
Effects of Regulation on Employment Using Alternative Comparison Regions

	South Coast	South Coast Texas Louisiana	US
Adoption	-3.3 (9.1)	1.0 (6.8)	-3.2 (6.7)
Compliance	5.4 (4.4)	3.0 (4.0)	3.1 (4.0)
Increased Stringency	7.9 (15.9)	-1.1 (12.3)	4.9 (11.8)
34 industry indicators	✓	✓	✓
50 state indicators	-	-	✓
N	1018	3104	18522
R^2	0.049	0.021	0.026

1. Each estimate includes 9 year indicators and an indicator for the South Coast Air Quality Management District. Standard errors are heteroskedasticity consistent. The mean of employment change is -6 for South Coast, -13 for California, and - 10 for full US.

2. "x Oil" is in each instance a variable set to one if a regulatory change (*e.g.*, adoption) occurred *and* it affected the petroleum industry (SIC code 2911).

Table VIII

Census of Manufactures: South Coast, Texas, Louisiana, 1977, 1982, 1987, 1992

Regulated Industries excluding Aerospace and Shipbuilding

	Mean	Standard Deviation
New adoption	0.15	0.41
x oil refinery	0.01	0.22
New compliance	0.25	0.59
x oil refinery	0.01	0.24
Increase stringency	0.05	0.24
x oil refinery	0.004	0.10
Employment	63	207
5 year change	-1.3	101
Value added	$5751	$31812
5 year change	$1487	$18963
Oil refinery	0.02	0.14
South Coast	0.47	0.50
Louisiana	0.10	0.30
Texas	0.43	0.49

21463 observations of 5 year differences, covering the periods 1977-82, 82-87, 87-92. Value added and employment levels are based on 15128 observations for the years 1982, 1987 and 1992. The sub-population includes all 55 regulated industries listed in Table A2 with the exception of 6 aerospace industries and shipbuilding (SIC codes 3721, 3724, 3728, 3761, 3764, 3769 and 3731). Value added is reported in thousands of constant 1991 dollars.

Table IX:
The Effect of Regulation on Employment between Census Years: 1977-82, 82-87, 87-92.

			Including Aerospace and Shipbuilding	Exit/Entry	Matched Plants	All States
Adoption	-2.8 (2.2)	-2.2 (2.2)	1.1 (6.6)	-1.7 (2.7)	-2.4 (3.4)	2.9 (2.0)
Compliance	2.2 (1.4)	2.2 (1.2)	-4.6 (4.8)	2.7 (1.6)	1.6 (2.0)	-2.7 (1.3)
x oil		-6.1 (9.9)	-3.7 (11.0)	0.3 (15.0)	-12.2 (12.6)	
Increased Stringency	-2.6 (4.2)	-4.1 (2.9)	9.4 (6.9)	-2.5 (3.4)	-6.1 (5.6)	1.2 (3.5)
x oil		17.8 (30.7)	12.7 (31.7)	-8.6 (55.7)	44.1 (25.0)	
S. Coast	-1.9 (1.9)	-1.9 (1.9)	-4.0 (4.7)	-3.9 (1.9)	0.2 (3.4)	0.3 (1.8)
Louisiana	-1.9 (2.5)	-1.9 (2.5)	-1.9 (3.3)	-4.6 (3.2)	1.2 (3.8)	-2.9 (4.1)
1982-87	-4.5 (1.9)	-4.3 (1.9)	-2.2 (4.7)	-3.1 (2.3)	-5.8 (3.3)	-4.7 (0.9)
1987-92	-4.5 (1.9)	-4.3 (1.8)	-11.0 (3.2)	-5.2 (2.1)	-2.7 (3.2)	5.1 (1.0)
Root MSE	101	101	292	97	106	158
R-square	0.01	0.01	0.003	0.02	0.01	0.01
Observations	21463	21463	24055	12593	8870	152823

Heteroskedasticity-consistent standard errors in parentheses. The census sub-population is described in the note to Table VIII. All specifications include indicator variables for four digit industries (48 for the regular sub-population, 55 for the sub-population including 6 aerospace industries and shipbuilding). The omitted region is Texas. The rightmost specification includes all nondefense plants in all states and includes a full set of state indicators.

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Appendix
Regulatory Change and PACE Databases

A. *Regulatory Change Data:*

The regulatory change data come from two different sources, (1) the California Air Pollution Control Laws, obtained from the California Environmental Protection Agency Air Resources Board (ARB), and (2) the South Coast Air Quality Management District Rules and Regulations Handbook. These two sources document all regulations required to be met by all polluters located in the South Coast Air Basin.

We exploit differences in environmental regulation that apply to plants in the SCAQMD to determine the impact of environmental regulation on labor market outcomes.[15] To do so, we first assign each regulation to one of the following four regulatory categories: (1) emissions standards; (2) technology standards; (3) emission or technology standards[16]; or (4) other.[17] Then, the target pollutant is identified for each regulation. Here, too, there are four categories -- VOCs, NOx, SOx, and other.

Almost all regulations prescribed in the SCAQMD for stationary source emitters are directed at processes, not industries. Part of the construction of the regulatory change data set consisted of mapping the impact of regulations onto Standard Industrial Classification (SIC) codes. While some regulations actually specify the SIC codes that will be affected, the bulk of them do not. The authors matched SIC to each regulation with the help of SCAQMD personnel.[18]

For each regulation, at least two dummy variables were created. One dummy is for the regulation's adoption date. A separate dummy was created for the compliance date. If the regulation includes a set of changing emissions standards that must be met at different points in time, separate compliance dates are given for each such time. By separating adoption and compliance dates, we can determine whether or not plants respond differently to the two events.

Since capital investment necessary to comply with a regulation must occur before the compliance date, regulations were backdated by a calendar quarter if investment or employment change is the variable to be explained.

Finally, the regulatory change data were matched to the LRD and PACE data set on a plant-by-plant basis, using SIC code information.

B. *LRD and PACE Data:*

The Longitudinal Research Database (LRD) combines plant level information from the Annual Survey of Manufactures (ASM) and the Census of Manufactures (CM) for all years from 1972-91. It contains data on employment, payroll, shipments and other "production function" variables. The CM is conducted every five years. The ASM is a stratified subsample of CM plants, supplemented annually with new establishments identified by the Social Security Administration. Plants with 250 or more employees are included with

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[15] The bulk of the air pollution control policies in the SCAQMD target nitrogen oxides (NOx), volatile organic compounds (VOCs), or sulphurous oxides (SOx). For example, Rule 1105 limits SOx emissions from fluid catalytic crachking units. Rule 1176 is an example of a technology standard, requiring replacement of sumps and wastewater separators with covered tanks and special equipment to limit VOC emissions.

[16] In such instances, the polluter is given the option of either meeting a particular emissions standard or installing a given type of control technology.

[17] The bulk of regulations in this category are "input standards", where the level of emissions of a particular input must fall below a given standard if it is to be used, sold, or manufactured in the SCAQMD. For example, Rule 1108 limits the VOC content of cutback asphalt that may be sold locally.

[18] §40440.8 (b)(1) requires that the SCAQMD determine the types of industries that will be affected by each of their rules or regulations.

probability one, and smaller plants are included with a probability proportionate to employment. The ASM sample is updated every five years based on the Census conducted two years previously. The certainty sample makes up about two-thirds of the LRD plants.

For 1979-91, except 1983 and 1987, we have a matched data set of LRD plants and plants reporting Pollution Abatement Costs and Expenditures (PACE). The PACE survey is conducted annually by the Census Bureau, using a subsample of ASM plants from a previous year (*e.g.*, the 1991 subsample uses the 1989 ASM). Selection probabilities are proportional to shipments. Each sampled plant has a PACE weight and an ASM weight, the product of which is its population weight. The sample was limited in size (17,000 observations in 1991).

LRD and PACE data were matched at the Census Bureau's Suitland Center for Economic Studies. Plants are considered to be "matched" over time if they exist in each year of the panel. They are identified by their permanent plant number.

Plants are asked to report both capital expenditures and other costs, for abatement of air, water and solid waste pollution. In the case of capital expenditures that involve a change in production process, the respondent is instructed to report "the difference between actual expenditures on new plant and equipment and what your establishment would have spent for comparable plant and equipment without air pollution abatement features". While this is exactly the question that we would like answered as economists, the Census Bureau feels that it confused respondents.

Table A1:
Number of Industries Affected
by New SCAQMD Regulations, 1980-91
(Four digit SIC industries, by year)

Year	Adoption	Compliance	Increased Stringency
1980	2	0	0
1981	0	0	0
1982	8	2	0
1983	0	3	0
1984	4	7	0
1985	2	4	0
1986	4	7	0
1987	0	3	0
1988	5	4	2
1989	5	0	0
1990	0	12	0
1991	2	3	5
Total	32	39	7

* More than one new regulation adopted.

Table A2:

Industries Affected through 1993 by SCAQMD Regulations

SIC Code	Industry Name	Adoption year(s)	Compliance year(s)
2051	Bread and other baked products	1991, 1993	1991, 1993
2052	Cookies and crackers	1991, 1993	1991
2053	Frozen bakery products	1991	1991
2211	Cotton broad woven fabrics	1979	1993
2221	Weaving mills, manmade fiber and silk	1979	1993
2231	Wool broad woven fabrics	1979	1993
2241	Narrow fabrics mills	1979	1993
2262	Finishing plants, manmade fiber and silk	1979	1993
2295	Coated fabrics, not rubberized	1979	1993
2297	Nonwoven fabrics	1979	1993
2426	Hardwood dimension and flooring	1978	1991
2431	Millwork	1978	1991
2451	Mobile homes	1978	1991
2452	Prefabricated wood buildings and components	1978	1991
2621	Paper mill products, except building paper	1979	1993
2631	Paperboard mill products	1979	1993
2641	Coated and glazed paper	1979	1993
2642	Envelopes, all types and materials (except stationary)	1979	1993
2819	Industrial inorganic chemicals, nec.	1985	1985, 1986
2821	Plastic matter, synthetic resins	1989	1990
2822	Synthetic rubber	1989	1990
2823	Cellulose manmade fibers	1989	1990
2824	Synthetic organic fibers (esp. cel.)	1989	1990
2834	Pharmaceutical preparations	1980	1990
2843	Surface active agents, finishing agents, and assistants	1984	1986

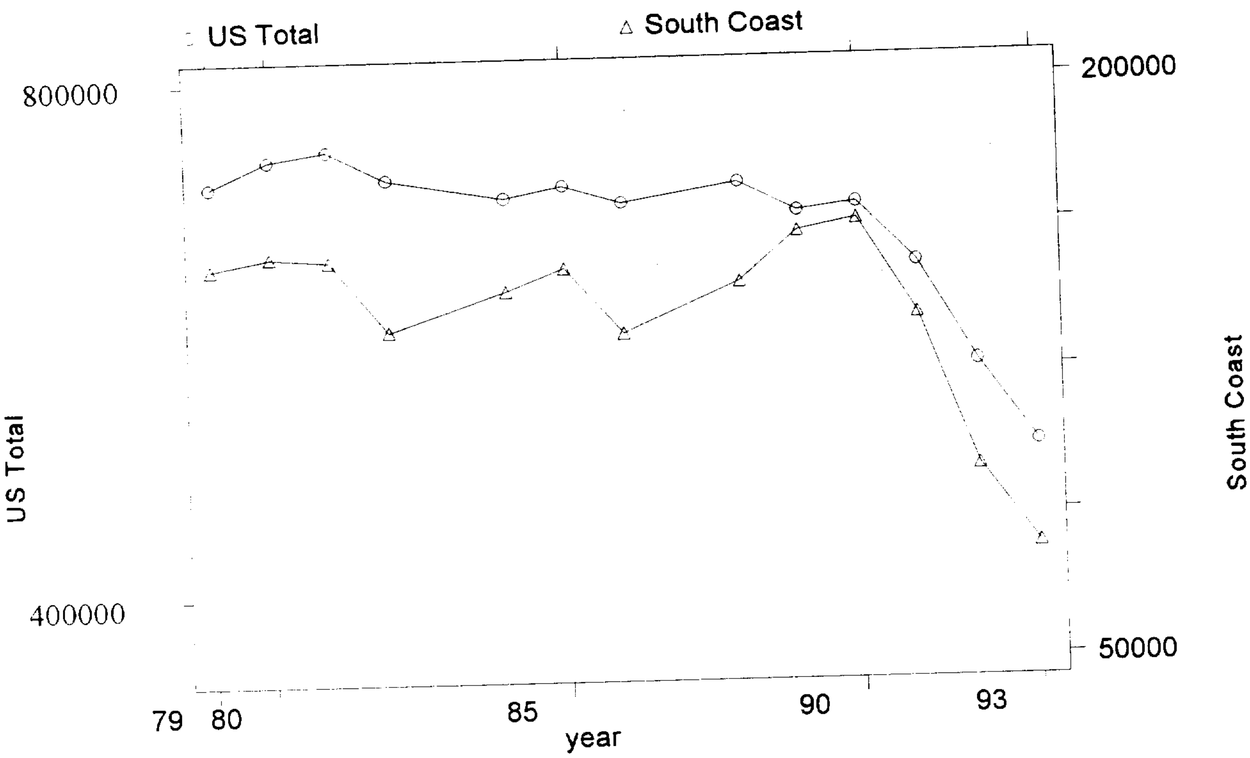
2844	Perfumes, cosmetics and related	1980	1990
2851	Paints, varnishes, lacquers & related	1977	1990, 1993
2873	Nitrogenous fertilizers	1985	1985
2893	Printing ink	1983	1992
2911	Petroleum refining	1978-80, 1982-84, 1989	1982-88, 1990-91, 1993
2999	Production of petroleum and coal, nec.	1979, 1983	1983, 1985
3221	Glass containers	1982	1988, 1993
3229	Pressed and blown glass(ware), nec.	1982	1987, 1992
3231	Glass production, made of purchased glass	1982	1987, 1992
3241	Cement, hydraulic	1982, 1986	1986
3271	Concrete block and brick	1982, 1986	1986
3272	Concrete products	1982, 1986	1986
3273	Ready-mix concrete	1982, 1986	1986
3315	Steel wire and related products	1979	1992
3341	Secondary smelting of non-ferrous metal	1977	1977
3357	Nonferrous wire drawing and insulating	1979	1992
3411	Metal cans	1979	1991
3652	Phonograph records and prerecorded tapes	1979	1992
3674	Semiconductors and related devices	1988	1990
3711	Motor vehicles and car bodies	1979, 1988	1984, 1990, 1992-93
3713	Truck and bus bodies	1979, 1988	1984, 1990, 1992-93
3714	Motor vehicle parts and accessories	1978-79, 1988	1984, 1990, 1992-93
3715	Truck trailers	1979	1984
3716	Motor homes produced on purchased chassis	1979	1984
3721	Aircraft	1979	1992, 1993
3724	Aircraft engines and engine parts	1979	1992, 1993
3728	Aircraft equipment, n.e.c.	1979	1992, 1993
3731	Ship building and repairing	1978, 1988	1991

Table A3:
Plants in Population, Samples, and Subsamples

Year	LRD Plants	PACE Plants	Matched PACE-LRD plants	PACE-LRD Plants matched with prior year
1979	57559	20123	12557	
1980	55953	20123	11935	11872
1981	55045	20002	11298	11104
1982	348384	18419	17508	7348
1983	51619	---	---	---
1984	56551	20009	18479	7876
1985	55128	20009	17213	16816
1986	59747	18047	15394	13500
1987	368895	---		
1988	53106	19505	16585	13876
1989	57276	16775	16153	5771
1990	~60000*	16803	15344	14540
1991	~60000*	16523	15721	14332

* Exact number unknown.

Figure II:
Aerospace and Shipbuilding Employment[19]



[19] Employment figures are from Annual Survey of Manufactures microdata which includes only a sample of plants. They underestimate total employment by 10-20%, though they accurately reflect trends. Aerospace is defined by SIC codes 3721, 3724, 3728, 3761, 3764, 3769 and shipbuilding by SIC code 3731.