Clearing the Air

The Impact of Air Quality Regulations on Jobs

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EXECUTIVE SUMMARY

The employment effects of environmental regulation have been hotly debated. Public opinion surveys show strong support for measures intended to produce a cleaner environment, but workers often feel that these measures threaten their jobs.

Is their anxiety justified? Economic theory and empirical studies to date are ambiguous on the employment effects of environmental regulation. Theory tells us that regulation can reduce employment by raising marginal costs and decreasing sales; it also tells us that regulation can increase employment by creating a demand for workers to monitor and maintain pollution control equipment. Empirical studies have produced conflicting results. Much of the ambiguity is probably due to the difficulty in accurately measuring the cost of environmental regulations and to the problem of distinguishing between firms with low abatement costs that voluntarily control emissions and firms with high abatement costs that adapt to the regulations reluctantly.

While the South Coast regulations imposed high costs on regulated plants, they had little effect on employment.

This study, by estimating the effect of regulation on employment directly, avoids the problem of attempting to measure abatement activity. It also concentrates on plants that have been forced to abate by regulation. Data on employment are drawn from Census Bureau observations of individual plants in the Census of Manufactures and the Annual Survey of Manufactures.

The analysis focuses on the regulation of air pollution in manufacturing plants in the Los Angeles region. Because this area has some of the worst air quality in the nation, the South Coast Air Quality Management District has been forced to adopt regulations of unprecedented stringency to comply with national air quality standards dictated by the Environmental Protection Agency. The study examines employment growth in the Los Angeles region in plants subject to these regulations, and compares growth at these plants to employment growth at similar plants in Texas and Louisiana, areas that had no significant increase in local air quality regulation.

The study finds:

- While the South Coast regulations imposed high costs on regulated plants, they had little effect on employment. There were about two jobs created per plant affected by South Coast regulations, though that number is not statistically different from zero. However, large job losses due to these regulations can be ruled out by the data.
- Job losses from induced exit and dissuaded entry due to regulation, as measured in the Census of Manufactures, were small.
- The oil industry in the South Coast, which was subject to particularly costly regulation, did not show evidence of a decline in employment relative to the facilities in Texas and Louisiana.
- A decline in military spending in the late 1980s and early 1990s caused significant job loss in the aerospace and shipbuilding industry in the Los Angeles

region during this period. The economic hardship that resulted may have contributed to the belief that air pollution regulations introduced during this period had reduced local employment.

The major finding of this study is that the most severe episode of increased air quality regulation of manufacturing industries did not have a large effect on manufacturing employment. This finding should inform debate on the effects of current and future increases in the stringency of national air quality standards.

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INTRODUCTION

The Environmental Protection Agency's recent recommendation to increase the stringency of national ambient air quality standards has intensified the continuing debate over the costs of environmental regulation in general and the cost in lost employment in particular. Regulation of the environment has increased sharply in the United States over the past quarter century as the public has demanded a cleaner environment. Although public opinion about the stringency of environmental regulation has ebbed and flowed with political and economic tides, the United States has joined and sometimes even led a worldwide trend toward more government intervention in the environment.

Despite years of debate, the consequences of these regulatory activities for labor markets are not well understood. Because regulation generally increases production costs, regulation is believed to reduce the demand for labor. Opponents of specific regulations typically argue that environmental controls will reduce employment in the local community. But how many jobs does environmental regulation actually cost? The answer to this question is critical to informed policy making.

Though the South Coast regulations imposed considerable abatement costs on manufacturing plants, they did not cause an appreciable loss of jobs.

Economic theory can give only limited guidance on these employment effects. Increased production costs due to regulations may cause firms to raise prices, which implies lower sales and less demand for labor. On the other hand, environmental regulation may increase the demand for labor if, for example, regulation causes firms to hire additional labor to maintain abatement equipment or carry out certain tasks specifically associated with the regulations.[1] The cost of regulation in lost production may also be small if regulations force a firm to adopt newer equipment that is cleaner but also more efficient. Regulation may also decrease local labor demand either by deterring entry of plants into local production or by inducing exit from the market or relocation to a region with less stringent regulation. Thus, empirical study is required as well. Unfortunately, the body of empirical study on the employment effects of regulation is largely inconclusive. (We explain below why we think that those studies led to imprecise estimates.)

In this study we provide what we think is compelling evidence regarding the impact of environmental regulation on manufacturing employment. We examine the experience of the Los Angeles region (the South Coast Air Basin), which introduced some of the most severe air quality regulations in the United States in the 1980s. Comparing changes in employment in regulated manufacturing plants in the South Coast to those of comparable plants not subject to local air quality regulation in other areas of the country yields a surprising finding: though the South Coast regulations imposed considerable abatement costs on manufacturing plants, they did not cause an appreciable loss of jobs. If anything, they increased employment slightly.

To understand why we think this evidence is compelling, it is necessary to examine the nature of air quality regulation and how its effects can be measured. In the United States, the story of national environmental regulation begins in 1970 with the establishment of the U.S. Environmental Protection Agency. Before that, regulation of environmental quality fell under the jurisdiction of state and local authorities, and few states or locales had adopted much more than nuisance-type laws. Since environmental regulation imposes costs on firms, there had been a concern that states would "race to the bottom," competing for business by enacting looser regulations than their neighbors. The EPA was established in part to prevent this race by establishing national environmental standards based solely on health criteria, not on economic benefit-cost analyses. For air pollution, these standards are known as the national ambient air quality standards (NAAQS), and they apply to six "criteria" air pollutants.[2] These standards have made environmental regulation pervasive in almost every aspect of industrial production — so much so that both industry and policy makers often express concern about the potential impact of these standards on the economy.

Policy decisions are almost invariably made without credible estimates of the employment effects.

Environmental regulation affects several different aspects of the economy. In this paper, we focus on the effects on employment in regulated manufacturing industries, an area in which massive increases in abatement spending have generated intense controversy.[3] There is a common perception of a tradeoff between jobs and a clean environment. Firms often refer to the "job loss" that a particular regulatory change will "cost" in a way that assumes that such a tradeoff in fact exists, especially where low-skill or production jobs are concerned. The issue of potential job loss looms over policy debates and influences decisions about both the adoption and stringency of environmental regulation.[4] But policy decisions are almost invariably made without credible estimates of the employment effects. Indeed, there is little empirical evidence on the magnitude or even the direction of the impact of environmental regulation on employment. This lack of empirical evidence is typical of research on the effects of environmental regulation on other aspects of the economy, such as output and productivity.

What we do know is that over the past 25 years the level of environmental regulation has increased dramatically due to public pressure to improve environmental quality. Since 1970, the cost of environmental regulation has risen rapidly. For example, pollution abatement and control expenditures (PACE) undertaken by U.S. manufacturing firms in response to environmental regulation increased by more than 44% between 1982 and 1991 alone — a compound annual rate of just under 4% (see **Table 1**). Pollution abatement capital expenditures for the nation during that period increased by 74%, a 6% annual rate. Not surprisingly, these costs have not been uniform across the nation: regions with high rates of pollution emissions or meteorological conditions unfavorable to the dissipation of air pollution have more difficulty meeting the national ambient air quality standards set by the EPA. For example, California's pollution abatement capital expenditures increased 20% faster than the national average.

The increase in environmental expenditure between 1982 and 1991 is impressive. To help put it in perspective, note that the cost of environmental regulation is estimated at approximately 1.5-2.5% of GDP.[5] In 1990, this cost would have been approximately $125 billion — about the same amount spent on research and development annually and not a lot less than the 3% of GDP spent on Medicare and

TABLE 1
Pollution Abatement and Control Expenditure Trends
(in Millions of Dollars)

Year		Capital Expenditures Total	Capital Expenditures Air	Gross Annual Cost Total	Gross Annual Cost Air
1991	U.S.	7,309.0	3,706.3	17,386.8	5,033.5
	California	696.6	443.7	1,717.0	616.4
	California/U.S.	9.4%	12.0%	9.9%	12.3%
Growth,	U.S.	74.1%	44.7%	44.6%	4.1%
1982-91	California	95.1%	94.4%	80.8%	37.4%

Source: Bureau of the Census (1979, 1991).

Medicaid. The sheer size of abatement costs suggests that the trend toward stricter and more pervasive environmental regulation may have dramatic implications for the economy as a whole.

As noted above, the literature on the impact of environmental regulation on the economy is far from conclusive. Why is there so much disagreement in these results and the opinions of participants in the debate? Estimated and predicted effects of environmental regulation may vary for a number of reasons. First, research thus far may have been confounded by what is referred to as "selection bias." Selection bias would occur if plants that can implement pollution reduction at low cost actually choose to do so without the impetus of regulation. Plants may choose to abate for many different reasons, including strategic purposes or in conjunction with changes in their production process that include cleaner, more efficient technologies. If researchers do not distinguish between pollution abatement expenditures undertaken by firms that are compelled to invest and firms that are voluntarily undertaking abatement expenditures, their studies will tend to *underestimate* the costs of regulation, since the small costs paid by those plants volunteering to abate will be averaged in with the higher costs imposed on plants forced to abate.

Studies that examine the statistical relationship between abatement expenditure (investment or operating costs) and economic outcomes are at risk of measurement error bias. Pollution abatement expenditure is an ambiguous concept that is notoriously difficult to quantify. For example, if a plant purchases a new boiler to replace an existing boiler for purely economic reasons and the new piece of equipment, being more efficient, produces less emissions, how much of that investment should be counted as pollution abatement control?[6] The allocation of managerial time to pollution control is also difficult to measure and is probably underestimated. To understand the bias that these measurement errors imply, consider a hypothetical study of two plants with identical employment levels and abatement expenditures. If abatement expenditure is overstated in one, we would compare the employment figures and falsely conclude that abatement expenditure has no effect on employment, even though it may have had a large effect. We would reach the same erroneous conclusion if abatement expenditure were understated in one of the plants.

Another reason for imprecise estimates is that the true effects of regulation may differ with the type of regulation chosen. Environmental regulation can take many different forms, as can the technical options available to plants to achieve compliance.[7] Thus, particular regulatory changes can conceivably affect labor demand in very different ways. For example, replacement of existing capital with newer, cleaner production facilities may reduce the demand for production workers, while the addition of end-of-line abatement technologies to existing facilities may increase labor demand. Compliance achieved through output reduction clearly reduces the demand for labor; on the other hand, the effect of regulation on output is unclear, since regulation-induced investment may lower marginal costs and thus raise output.

Employers may honestly overestimate the job loss caused by a pervasive regulation by not distinguishing between demand for its own product and product demand of the industry.

A final contributor to the confusion is that employers may honestly overestimate the job loss caused by a pervasive regulation by not distinguishing between demand for its own product and product demand of the industry. A single firm may face a large decrease in sales if it raises prices to meet increased abatement costs, since consumers will buy from a competitor. But if all the competing firms are subject to the same regulation, they will all be forced to increase prices, and the drop in sales may be quite small. In that case, the negative effect on employment through decreased sales may be dominated by the effect of the introduction of new equipment, which is often positive. The key to this argument is that competitors are subject to the same (local) regulations. We return to this point below when we see which industries are regulated.

In this paper, we present preliminary estimates, derived from a newly constructed dataset, that allow us to address the estimation problems that have frustrated research to date and to get directly at the labor market consequences of environmental regulation. We deal with the problems of selection and measurement error bias, as well as plant entry and exit issues, by estimating the effects of regulatory changes on employment directly. Since we look only at variation in abatement behavior induced by changes in local environmental regulation, our estimates are not contaminated by the behavior of firms that volunteer to abate. Also, precise measurement of regulation prevents bias due to measurement error.

The approach we take requires substantial variation in regulations and abatement behavior; we find these by examining local regulations and using data on individual plants. No study to date has sought to exploit microregulatory changes in environmental regulation, primarily because state and local regulation is so complex. While federal environmental regulations typically change every five to 10 years, state and local regulations vary a lot from year to year. Focusing solely on changes in federal regulations or on cross-state variation misses the bulk of the regulatory variation that affects manufacturing — the variation that may occur *within a state* as districts attempt to achieve and maintain compliance with federal standards and *within districts* as regulators choose to target some industries rather than others. The richness of our plant-level data allows estimation of the effects of regulation by comparing a regulated plant in an affected region with unregulated plants in the same narrowly defined industry not subject to those regulations.

Our study area, the South Coast Air Quality Management District (SCAQMD), consists of four counties in the South Coast Air Basin in Southern California in and around Los Angeles. Since 1977 the SCAQMD has introduced a large number of regulations affecting both industrial and nonindustrial sources of air pollution. Many of them are imposed with unprecedented stringency.

There is no evidence that environmental regulation decreased labor demand.

The comparison of "regulated" plants in the South Coast and "unregulated" plants in other regions yields accurate and precise results.[8] There is no evidence that environmental regulation decreased labor demand. In fact, we estimate very small positive effects, not significantly different from zero but precisely enough to rule out large negative effects. The result applies to both potential entrants and exiting plants, and to plants in the Census of Manufactures and the Annual Survey of Manufactures.

The paper proceeds as follows. The following section provides background about environmental regulation in general and in the SCAQMD in particular. Section II reviews the relevant literature on the impact of environmental regulation on labor markets and other outcomes. Section III describes the data, Section IV details the estimation of employment effects, and Section V offers some concluding remarks.

I. HOW REGULATIONS WORK

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 plans indicate how the state will ensure that all regions within the state will meet national standards. The federal EPA can withhold federal funds from states that do not submit SIPs, and it has the authority to take over environmental regulation if a state does not meet the national standards.

The Basin has some of the worst air quality in the United States, and it has enacted regulations far more restrictive than prevailing national standards.

In general, federal environmental regulations are limited to new sources of pollution (regulated by new source performance standards, or NSPS), except in regions that are out of compliance with federal standards or are deemed "pristine" (prevention of significant deterioration regions, or PSD). States are responsible for regulating existing stationary sources of pollution, as well as mobile sources.

Within California, air pollution is regulated at the state level by the California Air Resource Board (CARB). CARB takes responsibility for developing air pollution regulations for mobile sources of pollution and delegates regulation of stationary sources to local regulators, of which the South Coast Air Quality Management District is one.

California is divided into 34 air quality management districts (AQMDs), each responsible for developing its own regulations to control local air quality. The Basin, which consists of Los Angeles, Orange, Riverside, and the non-desert portion of San Bernardino Counties, falls under the jurisdiction of the South Coast AQMD. The Basin has some of the worst air quality in the United States, and it has enacted regulations far more restrictive than prevailing national standards. Since air quality regulation is becoming increasingly restrictive elsewhere, the experience of the South Coast can be used to predict the effects of similar regulatory changes in other jurisdictions. In fact, regulators in other regions often copy regulations previously enacted in the South Coast.

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 problems. Furthermore, it is an area of high industrial output and associated population growth. In 1990, the Basin accounted for 47% of the population of California and 4% of the population of the United States.

The SCAQMD shows significantly different pollution concentrations than other regions both within and outside California. Compared to most other large urban regions, the SCAQMD is considered to be further out of compliance with the national ambient air quality standards for criteria air pollutants than any other area. Even within California, the South Coast has a more extensive air pollution problem than the San Francisco Bay area or the San Joaquin Valley — the two other heavily industrialized and populated regions of the state.

In 1947, even before the advent of federal regulation of ambient air quality, Los Angeles County formed California's first Air Pollution Control District (APCD) to develop policies to improve ambient air quality. National ambient air quality standards were first established as part of the 1970 Clean Air Act for six criteria pollutants; at that time, the Basin was out of compliance with the new federal standards for four of them. In 1977, Orange, Riverside, and San Bernardino Counties joined Los Angeles County to form the SCAQMD, which was mandated to develop environmental regulations that would bring the Basin into compliance with federal standards. Since then, the Basin has significantly improved ambient air quality by adopting air quality regulations that are among the most stringent in the country. Between 1976 and 1993, the Basin reduced its annual out-of-compliance days by 47%, from 279 to 147. Nevertheless, in 1993 it remained out of compliance with three of the six federal ambient air quality standards (particulate matter, ozone, and volatile organic compounds), and had the highest annual average of particulate matter and nitrous oxide in the nation.

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Despite this improvement in ambient air quality, studies suggest that the health consequences of continuing noncompliance with federal standards may be great. Hall (1989) reports that over half the Basin population experiences a Stage 1 ozone alert annually, during which children are not allowed to play outdoors; minor eye irritations are experienced an average of 16 days per year by the average South Coast resident; and each such resident averages one day in which normal activities are substantially restricted. The annual per capita incremental risk of death from the Basin's noncompliance with federal standards is estimated at 1 in 10,000 (a risk that doubles in San Bernardino and Riverside Counties).[9] The same study estimates that the benefits of achieving compliance with federal ambient air quality standards would be over $9.4 billion annually — over $14.3 billion annually if the region were also to meet the more stringent California standards.[10]

II. RECENT EMPIRICAL STUDIES

A substantial body of empirical literature attempts to estimate the impact of federal environmental regulation on levels of productivity, output, prices, and labor demand. A puzzling aspect of this literature is that estimated effects vary widely. (For general surveys on this topic, see Jaffe et al. 1995 and Goodstein 1994.) Such studies fall generally into one of three categories: (1) studies on the effects of all federal environmental regulation on aggregates; (2) studies of the impact of specific federal environmental regulations on the behavior of industries; and (3) case studies of the effects of federal environmental regulation on specific industries.

A puzzling aspect of the empirical literature is that estimated effects vary widely.

The most striking feature of the first group of studies is that they do not reach a consensus on either the *magnitude* of the impact of regulation on the labor market or even its *direction* (i.e., positive or negative). Many of these studies estimate the effects of federal environmental regulation on aggregate productivity, output prices, and labor through simulations based on either engineering or econometric estimates of the cost of compliance in a general equilibrium framework. Increased production costs due to increases in the cost of compliance are translated into changes in prices, quantities, demand for labor, and productivity. Jorgensen and Wilcoxen (1990) is an example.

Work by Viscusi (1986) and Bartel and Thomas (1987) on the effects of the Occupational Safety and Health Act (OSHA) and EPA are good examples of studies of specific regulations and their effects. Viscusi examines the effect of OSHA on worker safety and fails to find any significant impact. 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 (1993, 1994) also find that regulation reduces manufacturing productivity. Henderson (1996) finds that counties switching from nonattainment to attainment status experience an incursion of dirty plants, presumably because of reduced regulatory stringency. Like the studies of the effects of federal environmental regulation on the overall labor market, no general conclusions can be drawn about the implications of environmental regulations for labor demand. Furthermore, it is often hard to reconcile the differences.

Many studies attempt to measure the effect of a particular set of environmental regulations on a specific industry. For example, Gollop and Roberts (1983), studying electric power plants, find that federal environmental regulation reduces productivity.

A second body of literature deals with both plant location choices and how governments might compete with one another through the use of environmental regulation. There has been a fair amount of empirical work done on how plant location responds to differences in state environmental regulations. A good example includes Levinson (1993), who examines plants in pollution-intensive industries and finds that environmental regulation has little impact on the location of new manufacturing plants (1982-87).

III. DATA DESCRIPTION

This study requires several datasets. Plant-level information on abatement is taken from the Pollution Abatement and Control Expenditures Survey, which we link to plant records contained in the Longitudinal Research Database (LRD) panel compiled by the Center for Economic Studies of the Census Bureau. Expenditures on pollution abatement are available by abatement categories — air, water, and hazardous waste — and are also classified by type – end-of-line capital outlays, operating and maintenance costs, and depreciation. To study plant-level exit and entry within manufacturing we use the Census of Manufactures.

The LRD is constructed from the Annual Survey of Manufactures, which samples the population of manufacturing plants, including large plants (250 or more employees) with certainty. Entry and exit of large plants are well measured by presence or absence annually; smaller plants, though, are rotated out of the sample at five-year intervals, so studying their entry and exit requires the Census. From these data we use the employment, value-added, and capital investment variables.

To date there is no comprehensive database on environmental regulations at any level other than the federal.

The Census of Manufactures 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.[11]

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 environmental regulations as a whole are the responsibility of the California EPA, and the SCAQMD is responsible for determining regulations specifically for the South Coast Basin.

From these sources we constructed a dataset 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. We tracked their adoption dates, compliance dates, dates of increases in stringency and the pollutant involved, and the method of compliance. We used the regulation books, the SCAQMD library, and a series of conversations with both the regulators and the regulated plants to establish the timing and coverage of regulations.

The number of possible regulatory categories that can be constructed by interpreting a given text is unbounded. Regulations have many attributes, so decisions must be made in coding this information. 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 for our analysis. Thus, in converting the regulation books into indicator variables, there is a potential for "overfitting" the regression by coding the regulations so that they will better explain the data. We avoid this bias with a unique solution. The coding method was agreed on *before* we saw the data, and all decisions about the coding are made by an individual who does not estimate the coefficients. We feel that this method of sequestering the data is crucial to obtaining unbiased inferences from microregulatory data.

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 a panel of plants and their PACE from the LRD-PACE match for the years 1979-91 (excluding 1983 and 1987).[12] For each plant-year we count new regulations adopted, new regulations that must be complied with, and increases in stringency of existing regulations. Regulations were matched to industries using the text of the regulation, our understanding of production technologies, and the opinions of regulators at the SCAQMD. Our sample consists of all manufacturing plants in the United States in industries affected by SCAQMD regulations. This panel averages 1,852 plants per year.

Table 2 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. The weighted (population) means show that in these industries annual

TABLE 2
Means and Standard Deviations

Variable	Mean	Weighted Mean	Weighted Std. Dev.
Air Pollution Abatement			
Capital Investment:			
Net*	330	104	1,877
Gross*	444	142	1,927
Process*	137	43	1,110
End of Line*	308	99	1,412
Operating and Maintenance			
Costs*	845	273	2,763
Change*	3	0.4	1,399
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:*	72,860	25,689	100,584
Change*	-1,785	-600	50,584
Employment:	681	267	868
Change	-26	-10	173
L.A. Basin (%)		5.3	22.4

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

* Thousands of 1991 dollars deflated by producer price index.

Source: Authors' analysis.

TABLE 3
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	0.04	0.10
Employment	63	207
5-year change	-13	101
Value added	$5,751	$31,812
5-year change	$1,487	$18,963
Oil refinery	0.02	0.14
South Coast	0.47	0.50
Louisiana	0.10	0.30
Texas	0.43	0.49

Note: Based on 21,463 observations of five-year differences, covering the periods 1977-82, 1982-87, 1987-92. Value-added and employment levels are based on 15,128 observations for the years 1982, 1987, and 1992. The subpopulation includes all 55 regulated industries listed in Table A2 with the exception of six aerospace industries and shipbuilding (SIC codes 3721, 3724, 3728, 3761, 3764, 3769, and 3731). Value added is reported in thousands of constant 1991 dollars.

Source: Authors' analysis.

abatement capital investment and operating costs are high: capital investment costs averaged $104,000 per plant, and operating costs averaged $273,000 per plant, representing about 1.5% of value added. There is also a lot of variance between plants in these costs, with standard errors that are an order of magnitude larger than the means. This is a reflection of the large costs incurred by petrochemical and chemical plants.

Note that 5.3% of the sample plant-years are located in the Los Angeles Basin. In slightly less than one-fifth of these years (0.96% of the whole sample or 580 plant-years), these plants were subject to new compliance regulations.

Table 3 reports sample means and standard deviations for the regulated industries (as described above, excluding aerospace and shipbuilding) from the Census of Manufactures for 1977, 1982, 1987, and 1992. Three regions are included in this analysis: the South Coast Air Basin, Texas, and Louisiana. The subpopulation includes 21,463 observations of five-year differences. An average of 0.15 new regulations annually affected each plant in the sample, with 0.25 occurrences of compliance dates and 0.05 of increased stringency. These industries tend to have large plants, with an average of 63 employees and $5.8 million of value added.

IV. ESTIMATION OF EFFECTS

In Section II, we argued that the existing literature on the effects of pollution abatement and control expenditures on employment was of limited use to policy makers, since the reports of estimated effects vary markedly in both size and sign. The disparity and instability of the existing estimates may be the product of selection bias and measurement error, both of which can be addressed by estimating the effect of regulation on employment directly, using well-measured regulations.

Pollution abatement and control expenditure is often poorly measured, both because data are missing and because the distinction between investments in new capital and pollution abatement capital can be subtle.

Selection Bias

Selection bias in the estimated effect of abatement on employment would occur if plants that can implement pollution reduction at low cost choose to do so without the impetus of regulation. Plants may choose to abate for many reasons, including strategic purposes or in conjunction with changes in their production process that include cleaner, more efficient technologies. If researchers include in their evaluation of the cost of regulation plants that *voluntarily* choose to abate pollution, they are likely to *underestimate* the costs of a regulation that forces all firms to abate, since the low-cost firms are more likely to have volunteered. This may explain the surprising Gray and Shadbegian (1993) result that PACE is *positively* correlated with employment. In contrast, the use of regulatory change serves to reconstruct the experiment in which we are really interested: induce plants to carry out PACE and then observe the results.

Measurement Error

PACE is often poorly measured, both because data are missing and because the distinction between investments in new capital and pollution abatement capital can be subtle.[13] (For example, new equipment is often both more efficient and cleaner.) This is a type of measurement error, and it may induce an underestimate of the impact of PACE in an ordinary least squares (OLS) regression of employment on PACE. Regulatory change variables can deal with this problem, too, by using only the variation in PACE attributable to regulatory change.

An additional problem that arises in the use of regulatory change as a variable is that measurement of treatment effects may be frustrated when changes in behavior are made in anticipation of a 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 (often years before). If plants adjust behavior in anticipation of having to comply with a regulation, we expect to see that adjustment on the adoption date. By including an indicator for that date in the set of regressors, we attempt to measure the extent of anticipatory reaction to regulatory change. In the case of environmental regulation, this type of reaction is unlikely, since compliance typically involves high costs that a firm has no reason to incur ahead of time.[14]

We have restricted ourselves to three binary indicators for our regulation variable: adoption dates, compliance dates, and dates of increased stringency in existing regulations.[15] These dates were determined by the method discussed earlier in Section III.[16]

This method uses comparison plants to represent the employment growth that the South Coast plants would have experienced in the absence of regulation. Comparison plants are matched to South Coast plants by a precise industry classification (four-digit standard industrial classification, or SIC, code). Intuitively, this method can be thought of as comparing the employment change in an oil refinery in the South Coast subject to a new regulation to that of an unregulated refinery in Texas. The comparison plant allows us to control for industry-specific changes in employment. In that example, if the newly regulated plant increased employment by 10 workers and the comparison plant increased employment by 20 workers, we would attribute the slower employment growth of the South Coast plant to the new regulation. To increase statistical precision, South Coast and comparison plants were grouped in industry cells. Unregulated plants were added to the mix to allow for region-specific changes in employment. We will see below that this use of comparison groups is especially important for our study, since many of the regulated industries experience changes in employment for secular reasons such as increased productivity or decreased demand from defense contracts.

The comparison plant allows us to control for industry-specific changes in employment.

The assumption that regulations and unexplained variation in employment are independent is conditional on inclusion of plant indicators and year indicators in the regression. (Regulatory change is most likely correlated with plant characteristics such as location and probably bunched in particular years.) This assumption is a claim that regulatory changes are correlated with employment changes only through their direct causal effect, once the common effect of time is accounted for. In short, we claim that the "bad luck" of being located in the Los Angeles Basin is a fixed effect.

The coefficients in these regressions are estimates of the effects of *local* regulatory change on employment. These estimates should provide a tool for local policy makers to use in predicting the local employment effects of similar regulatory changes (e.g., raising standards for airborne pollutants). These estimates must be interpreted with care. Since the comparison group for a group of regulated plants is the set of plants in the same industry in the rest of the country, combined with plants in the same industry in the same region in years with no change in regulation, 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 or in the same region in years in which the same industry was subject to no new regulation.

Results

Before investigating the direct relationship between regulation and labor demand, we check our measures of regulation by estimating the effect of microlevel environmental regulation on pollution abatement capital expenditures. These results are reported in **Table 4**.

The data used in this regression are a panel that includes plants in all industr-

TABLE 4
The Effect of Changes in Regulation on Changes in Air Pollution Capital Investment

	1	2	3	4
Adoption	-65	-144	-149	-11
	(218)	(184)	(184)	(55)
x oil	-	-	-	413
				(571)
Compliance	640	525	528	-33
	(243)	(228)	(227)	(39)
x oil	-	-	-	2,745
				(1,048)
Increased Stringency	2,144	1,795	1,803	-248
	(1,071)	(1,037)	(1,034)	(146)
x oil	-	-	-	7,006
				(2,929)
34 industry indicators	-	✓	✓	✓
50 state indicators	-	-	✓	✓
N	18,522	18,522	18,522	18,522
R^2	0.011	0.039	0.041	0.058

Note: Each estimate includes nine-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 (thousands of 1991 dollars).

"x oil" is in each instance a variable set to 1 if a regulatory change (e.g., adoption) occurred *and* it affected the petroleum industry (SIC code 2911).

Source: Authors' analysis.

ies affected by SCAQMD regulation in the 1979-91 period, with plants from the rest of California and the remaining states included as comparisons. Plants must be in the panel for at least two successive years to be included in this sample of first-differences. The results indicate that compliance dates and dates in which regulatory stringency are increased have large and significant effects on abatement investment. Note that the units are thousands of dollars (constant $1991), so that the coefficient on compliance implies a half million dollars of capital investment for each new regulation. The results are essentially unchanged by the inclusion of industry and state effects. The first row indicates no evidence that adoption of regulations into law has any effect on abatement investment, although it seems to suggest a puzzling negative effect that is large and marginally significant. The coefficient on increased stringency indicates a possible large but poorly estimated effect on investment. The right-most column estimates 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 other estimated effects insignificantly different from zero.

Table 5 reports the estimated effects of regulatory changes on employment. The estimates suggest small employment *increases* due to compliance dates with environmental regulation. While these estimates do not rule out zero effects, they do rule out the large negative effects (job loss) generally attributed to environmental regulation.

The results in Tables 4 and 5 provide an interesting contrast. Though air quality regulation induces large investments in abatement capital, it has no discernible effect on value added and seems to have no negative effect on employment. The regulations probably caused small increases in employment. These results are con-

TABLE 5
Effect of Changes in Regulation on Changes in 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	18,522	18,522	18,522	18,522
R^2	0.011	0.023	0.026	0.026

Note: Each estimate includes nine-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.

"x oil" is in each instance a variable set to 1 if a regulatory change (e.g., adoption) occurred *and* it affected the petroleum industry (SIC code 2911).

Source: Authors' analysis.

sistent with the idea that complementarity between pollution abatement capital and labor could more than compensate for small output effects of regulation, thus providing a net positive effect of air quality regulation on labor demand.

As a check to see whether the above results were sensitive to the comparison group chosen, we re-ran our regression with alternative comparison regions. These results are presented in **Table 6**. The first column of Table 6 includes only South Coast regulated plants in the sample, so here the only comparison group is the same plants in years in which regulation did not change. Column 2 uses the rest of California as the comparison group. Column 3 is the same as column 3 in Table 5, using the rest of the United States as a comparison. The results in Table 6 are consistent with those found in Table 5: regardless of the comparison region that we use, environmental regulations appear to have a small positive effect on labor demand during the compliance and increased stringency dates. These estimates are precise enough to rule out large scale job loss due to the SCAQMD regulations.

Regardless of the comparison region, environmental regulations appear to have a small positive effect on labor demand during the compliance and increased stringency dates.

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, and thus these potential employment effects of regulation have gone unmeasured. Cost-minimizing behavior is unambiguous about induced entry and exit. The effects

TABLE 6
Estimates Using Alternative Comparison Regions:
Effect of Changes in Regulation on Changes in Employment

	South Coast	California	USA
Adoption	-3.3 (9.1)	1.0 (9.6)	-3.2 (6.7)
Compliance	5.4 (4.4)	6.3 (5.8)	3.1 (4.0)
Increased Stringency	7.9 (15.9)	24.7 (23.8)	4.9 (11.8)
34 industry indicators	✓	✓	✓
50 state indicators	-	-	✓
N	1,018	1,926	18,522
R^2	0.049	0.03	0.026

Notes: Each estimate includes nine-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 U.S.

Source: Authors' analysis.

of new regulation on employment through entry and exit must be negative for the regulated industry, since there is no technical complementarity without production.[17]

To capture the effects of regulation through exit and dissuaded entry we turn to the Census of Manufactures, a five-year enumeration of all manufacturing plants (a number between 300,000 and 400,000).

The 1977, 1982, 1987, and 1992 Censuses provide a three-period panel of five-year differences to estimate the effect of environmental regulation on labor demand. We select the subpopulation of plants in regulated industries in the South Coast and include for comparison plants in the same industries in Texas and Louisiana. These two states were 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; they are also relatively free of local air quality regulation. This is key to this analysis. In order 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.

Could some of the decrease in aerospace employment in the South Coast have been due to environmental regulation? It is possible, but the impact was probably small.

One weakness of the Census-to-Census comparison is that, over a five-year period, other events may occur in regulated industries in the Los Angeles Basin that confound analysis of the effects of regulation. One such event is the sharp decrease in orders for defense-related products that occurred as the federal government reduced spending on "Star Wars" and other programs. These cutbacks led to considerable job loss in the aerospace industry of Southern California, an industry that happened to be subject to two environmental regulations in the 1987-92 period.

Aerospace and shipbuilding are closely tied to Defense Department contracts. In fact, about three-quarters of all Defense Department contracts in manufacturing are accounted for by these industries.[18] The top line in **Figure 1** tracks aerospace and shipbuilding employment in the entire United States, and 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, a rate that parallels a sharp national decrease over the same period. Most of these losses at the national level occurred in regions that did not impose new environmental regulations on these industries in this period.

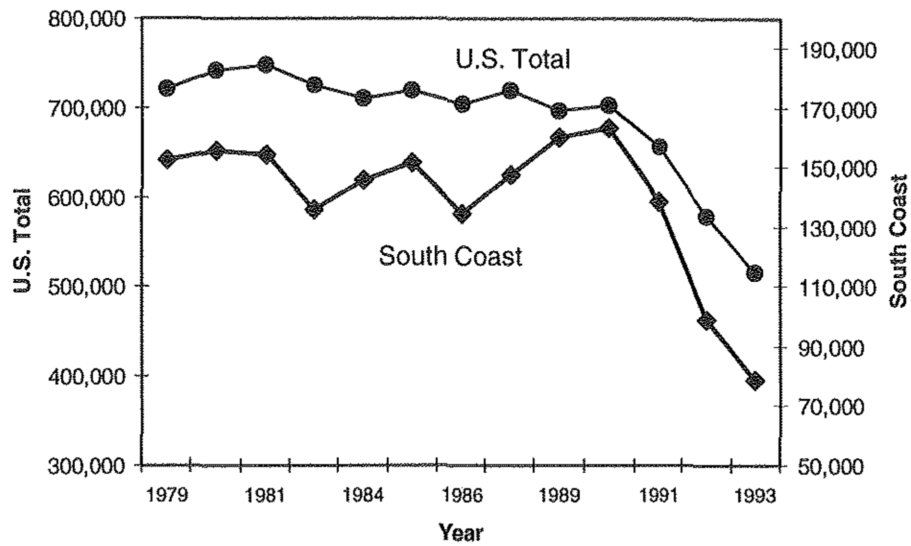
Could some of the decrease in aerospace employment in the South Coast have been due to environmental regulation? It is possible, but the impact was probably small. Most of these industries were affected by only one regulation concerning coatings, which had a compliance date of January 1993, long after the sharp downturn in employment.[19] In any case, Figure 1 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 a subpopulation of the Census of Manufactures that excludes the aerospace and shipbuilding industries. Descriptive statistics for this panel of plants are reported in Table 3.

Recall that the reason for using the Census data was to enable an accounting for exit and entry. The Annual Survey of Manufactures changes its sample of smaller

FIGURE 1

Aerospace and Shipbuilding Employment*



* 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, and 3769, and shipbuilding by SIC code 3731.

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. Equation (2) in Appendix B, in which we examined the effect of changes in regulation on changes in employment, 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. Those five-year changes in employment are reported in Table 3 for both continuing plants and for entrants and departing plants.

Table 3 reports three periods of five-year changes in employment: 1977-82, 1982-87, and 1987-92. Average employment change for a plant over these five-year periods, including employment increases for entrants and decreases for exits, was a drop of 1.3 employees. 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, while 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.

Table 7 reports the estimation results. The first column provides results for all (non-defense-related) plants — continuing, entering, and exiting. Employment increased by 2.2 persons for each new compliance regulation and decreased by 2.6

of new regulation on employment through entry and exit must be negative for the regulated industry, since there is no technical complementarity without production.[17]

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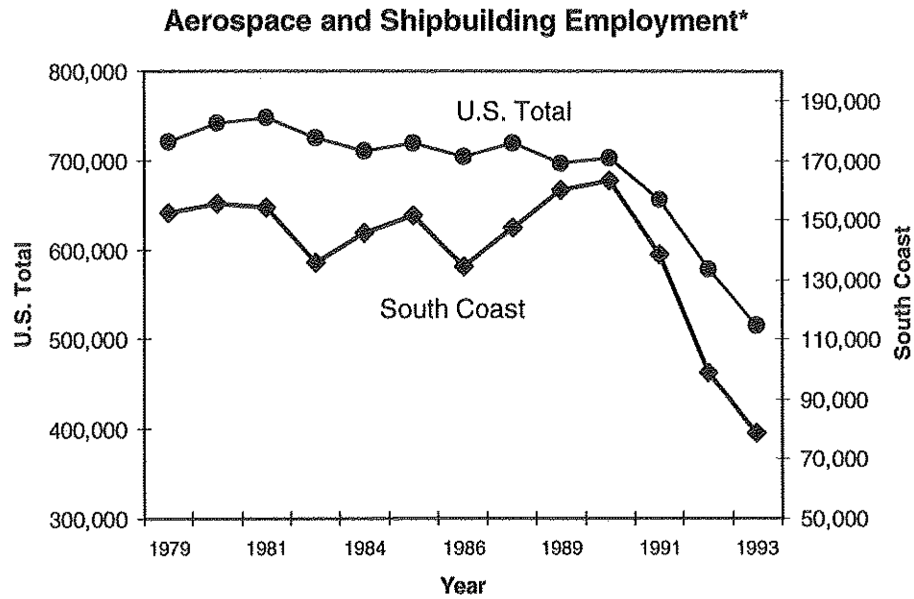

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Table 7 reports the estimation results. The first column provides results for all (non-defense-related) plants — continuing, entering, and exiting. Employment increased by 2.2 persons for each new compliance regulation and decreased by 2.6

TABLE 7
The Effect of Regulation on Changes in Employment Between Census Years: 1977-82, 1982-87, 1987-92.

	All Nondefense Plants		Including Aerospace and Shipbuilding	Exit/Entry	Matched Plants
Adoption	-2.8	-2.2	1.1	-1.7	-2.4
	(2.2)	(2.2)	(6.6)	(2.7)	(3.4)
Compliance	2.2	2.2	-4.6	2.7	1.6
	(1.4)	(1.2)	(4.8)	(1.6)	(2.0)
x oil		-6.1	-3.7	0.3	-12.2
		(9.9)	(11.0)	(15.0)	(12.6)
Increased Stringency	-2.6	-4.1	9.4	-2.5	-6.1
	(4.2)	(2.9)	(6.9)	(3.4)	(5.6)
x oil		17.8	12.7	-8.6	44.1
		(30.7)	(31.7)	(55.7)	(25.0)
South Coast	-1.9	-1.9	-4.0	-3.9	0.2
	(1.9)	(1.9)	(4.7)	(1.9)	(3.4)
Louisiana	-1.9	-1.9	-1.9	-4.6	1.2
	(2.5)	(2.5)	(3.3)	(3.2)	(3.8)
1982-87	-4.5	-4.3	-2.2	-3.1	-5.8
	(1.9)	(1.9)	(4.7)	(2.3)	(3.3)
1987-92	-4.5	-4.3	-11.0	-5.2	-2.7
	(1.9)	(1.8)	(3.2)	(2.1)	(3.2)
Root MSE	101	101	292	97	106
R-square	0.01	0.01	0.003	0.02	0.01
Observations	21,463	21,463	24,055	12,593	8,870

Note: Heteroskedasticity-consistent standard errors in parentheses. The Census subpopulation is described in the note to Table 3. All specifications include indicator variables for four-digit industries (48 for the regular subpopulation, 55 for the subpopulation including six aerospace industries and shipbuilding).

Source: Authors' analysis.

persons for each new increase in stringency. 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. This analysis implies a fairly precise estimate of the cumulative effect on employment of 14 years of air quality regulation in the South Coast: 9,000 jobs created, with a 95% confidence interval ranging from -6,400 to +24,400 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 1. However, large negative employment effects can be ruled out.

The second column reports a specification including oil refineries, as in Table 4. This increases the size of the negative coefficient on stringency for nonrefineries and increases the accuracy of estimation. Again, large employment effects for nonrefineries can be ruled out, and employment effects for refineries have positive point estimates. It is worth emphasizing that, unlike the estimates in Table 4, these estimates include the effect of regulation through entry and exit. This means that these estimates also include the employment effect that is attributable to plants that move because of regulation.

Column 3 shows the effect of ignoring government contracts and including defense-related industries in Table 7. That estimate implies large negative employment effects. This confusion between the effects of decreased defense contracts and the effects of environmental regulation may explain why environmental regulation was implicated for the job loss in South Coast manufacturing. As we argued in the discussion of Figure 1 above, that is a false inference.

The results clearly rule out large job loss due to environmental regulation, even when dissuaded entry and exit are taken into account.

Columns 4 and 5 examine entry and exit explicitly, breaking up the subpopulation in column 2 into separate entry/exit and continuing plant subpopulations. Surprisingly, we find coefficients of similar size for exiting and entering plants 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 the estimates here. Although the Census includes all plants, it is not designed for longitudinal study, and therefore the firm identifiers may change between waves of the Census; this can cause a continuing plant to be falsely classified as an exiting or entering plant. For example, if a continuing plant has an employment decrease from 55 to 50 employees over the five years between Censuses, the employment change should be recorded as -5. But if its identification number is changed between Census years, it will be misclassified as an exiting plant with 55 employees and then as an entering plant with 50. However, we are fairly confident that this kind of misclassification is uncorrelated with regulatory change, so that it does not bias our estimates.

The effects for both entry/exit and continuing plants are small, positive, and not statistically distinct from zero. While employment gains due to exit and entry are unlikely, a positive employment effect may be due to misclassification of continuing plants as exit/entry combinations. The results clearly rule out large job loss due to environmental regulation, even when dissuaded entry and exit are taken into account. These estimates serve to reinforce the results in Tables 4 and 5.

CONCLUSION

Our results indicate that in the 1979-91 period in the Los Angeles Basin, increases in air quality regulation did not appreciably affect employment. In contrast to the widespread belief that environmental regulation of industry costs jobs, the most severe episode of air quality regulation of industry in U.S. history probably created a few jobs.

The basic result — that air quality regulation in the South Coast did not cost jobs in the regulated industries — is found in two separate datasets. In the Annual Survey of Manufactures we found no job loss in the short term. In the Census of Manufactures we found no job loss at five-year intervals. This latter finding is true even when entering and exiting plants are included. The study uses precise measures of regulation and a large number of comparison plants to control for the possibility of measurement error and selection bias.

In contrast to the widespread belief that environmental regulation of industry costs jobs, the most severe episode of air quality regulation of industry in U.S. history probably created a few jobs.

The finding of no job loss contradicts the common perception that environmental regulation costs jobs, but it is not necessarily surprising. Economic theory is ambiguous about the employment effects of a regulation, and theory in fact points to a likely explanation: the job loss due to reduced sales could be smaller than the job gain due to abatement activity in the plants. If firms sell in a local market in which all of their competitors face the same regulations, the reduction in sales due to regulation may in fact be small. Also, for the industries most affected by air quality regulation — petroleum refining, power generation, and, to a lesser extent, chemicals — the market is quite local, so the lack of job loss is not so surprising. Moreover, those same industries employ relatively few workers in the first place, so there are not that many jobs at risk. Finally, air quality regulation may have been falsely implicated for causing job loss in South Coast manufacturing because of the overlapping effects of defense cutbacks, which decreased employment even in areas unaffected by local environmental regulation.

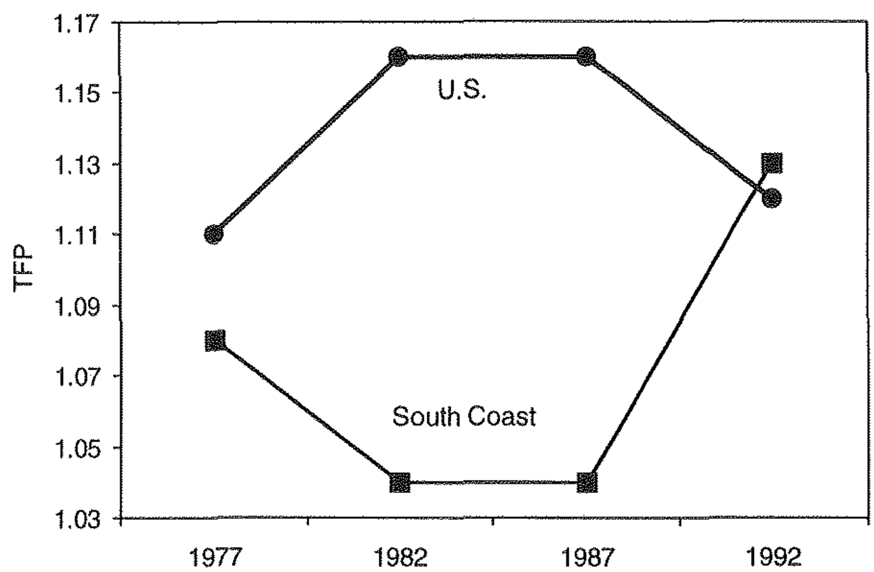
Small employment effects are also surprising, considering the evidence that regulations induced hundreds of millions of dollars of abatement investment. That much investment in abatement would be expected to reduce productivity and probably increase marginal costs and goods prices, thus reducing sales and employment. Preliminary results from a related study on the effect of air quality regulation on the productivity of oil refineries challenge that reasoning.

Oil refineries incurred the lion's share of abatement costs in the South Coast. They were subject to a series of extremely expensive regulations in the 1987-92 period that caused abatement investment to quadruple (it reached 3% of revenues in 1992), a much faster rate of increase than that for refineries in the rest of the United States. Preliminary results on the productivity of oil refineries indicate that, despite these increased costs, refineries actually became *more* productive during that period. In contrast, the rest of U.S. refining suffered a productivity decline. In order to make sure that this result is not due to differential changes in prices in the South Coast, we calculated productivity with prices of both inputs and outputs held constant across time and regions.[20] **Figure 2** illustrates the comparison of total factor productivity in South Coast and U.S. refineries at fixed prices. The South Coast refineries clearly increased productivity even as they carried out expensive investments in abatement capital. While these results are preliminary, they do suggest the need for caution in interpreting abatement costs as a gross cost rather than as a net loss, since abatement inputs may well be productive.[21]

The lack of negative employment effects combined with preliminary evidence of increased productivity associated with environmental regulation suggests that much of the concern about the costs of regulation is misplaced. More careful study is needed to establish what the true costs of air quality regulation are, not to mention the benefits. The preliminary conclusion here is that the conventional wisdom may drastically overestimate the cost of clean air.

FIGURE 2

South Coast & U.S. Total Factor Productivity 1977-92 (Fixed Prices)



Source: Authors' analysis.

APPENDIX A
Regulatory Change and PACE Databases

Regulatory Change Data

The regulatory change data come from two different sources: (1) the California Air Pollution Control Laws, obtained from the California Air Resources Board (CARB), 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.[22] 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,[23] or (4) other.[24] Then, the target pollutant is identified for each regulation. Here, too, there are four categories – volatile organic compounds, nitrous oxide, sulfurous oxide, 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 dataset 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.[25] For each regulation, at least two dummy variables were created. One dummy was for the regulation's adoption date; a separate dummy was created for the compliance date. If the regulation included a set of changing emissions standards that must be met at different points in time, separate compliance dates were given for each such time. By separating adoption and compliance dates, we could determine whether plants responded 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 was the variable to be explained.

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

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 to 1991. 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 probability 1, 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 the years 1979-91, except 1983 and 1987, we have a matched dataset of LRD plants and plants reporting pollution abatement and control expenditures. 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

Source: Authors' analysis.

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

Source: Authors' analysis.

TABLE A3
Plants in Population, Samples, and Subsamples

Year	LRD Plants	PACE Plants	Matched PACED-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.

Source: Authors' analysis.

APPENDIX B
Labor Demand and Environmental Regulation

There are two useful ways in which we can think about how environmental regulations affect a plant's decision about its desired level of employment. First, a plant's decision on the level of employment can be viewed simply as a function of its output level, abatement activity (measured by the capital, operating, and maintenance cost associated with abatement control), and the prices of other factors of production (materials, labor, and capital)[26]:

$$(1) \qquad E = \alpha + \rho_Y Y + \sum_{k=1}^{L} \gamma_k P_k + \sum_{k=1}^{M} \beta_k Z_k .$$

Notice that in (1), environmental regulation affects labor demand through its affect on output levels, abatement activity, and the price of other factors of production.

A different way to think about the effect of regulation (R) on labor demanded is to look at the direct relationship between the two, which may be summarized as:

$$(2) \qquad E = \delta + \mu R.$$

The relationship between (1) and (2) may be seen by looking at how a change in the level of regulation affects the demand for labor. The mechanism by which these effects take place is:

$$(3) \qquad \frac{dE}{dR} = \rho Y \frac{dY}{dR} + \sum_{k=1}^{M} \beta k \frac{dZ_k}{dR} + \sum_{k=1}^{L} \gamma k \frac{dP_k}{dR} = \mu .$$

What this implies is that environmental regulation can affect employment via three channels — through its effects on output, abatement activity, and factor prices. If input markets are large and competitive, regulatory change will not affect input prices because it affects too few jobs. Thus, the last mechanism can be ignored, leaving the effects through output and through abatement activity.

The output effect of environmental regulation is widely believed to be negative, although economic theory gives no such prediction:[27] if compliance is achieved through an investment that reduces marginal costs, dY/dR could be positive because at lower marginal costs a firm may increase production. The second term reflects the impact of regulation on labor demand through its effect on the use of abatement equipment and other abatement costs. Here the coefficient reflects whether that equipment substitutes or complements labor. Abatement equipment complements labor if its introduction requires a net increase in employment. This is common for end-of-pipe equipment and various types of monitors, which require extra workers to operate them. Abatement equipment often substitutes labor if it is part of a larger capital investment that is labor saving. Since increased regulation increases the use of abatement equipment, the key to understanding the direction of this effect is its complementarity or substitutability with labor.

The employment effects of regulation cannot be predicted by theory alone, which is ambiguous in any case. Economists tend to think that output effect is negative; which of the two terms is bigger is unclear. What is unambiguous is that if firms are forced to exit or dissuaded from entering by regulation, the employment effects of that regulation will be negative.

APPENDIX C
A Model of Labor Demand Under Regulation

We now outline a more technical model than that which is described in Appendix B that allows separate estimation of the effects of regulation on labor demand via two separate mechanisms, the output elasticity of labor demand and the marginal rates of technical substitution between different types of capital 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. That approach may be applied to the problem under study by treating any cost incurred to comply with environmental regulation — including 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, then, 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, P_l are prices of variable inputs, and Z_m are quantities of quasi-fixed inputs.

Profit maximization implies a set of first-order conditions that will yield demands for the variable inputs X_j that are functions of prices, output, and quantities of the quasi-fixed inputs, which we approximate by the linear equation:[28]

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

Assuming that input prices of the variable factors are exogenous at the plant level and that valid instruments exist for output, input prices, and quasi-fixed factors, the parameters of (2) can be estimated.

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 mechanism by which these effects take place can be written as:

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

If input markets are large and competitive, regulatory change will have no effect on input prices, so the final term in (4) will be zero,[29] and the effect of regulation reduces to the sum of the first two terms. The first term reflects the effect of regulation on demand for variable factors through its effect on output. The output effect of environmental regulation is widely believed to be negative, although economic theory gives no such 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 factors, such as pollution abatement expenditures, and the marginal rates of technical substitution between quasi-fixed and variable factors. The change in demand for quasi-fixed factors due to an increase in regulation, dZ/dR, must be positive, but β cannot be signed a priori. The effect of regulation on output and quasi-fixed factors are estimated as "first stage" equations in the instrumental variable strategy outlined below. Note that the only identifying assumptions required for this decomposition are the linearity of demand for variable factors in (3) and large competitive input markets.

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. Nevertheless, evidence of the effect of regulation on Y and Z (the "first stage") will help us interpret the estimated effects of regulation on employment in (3). Those first stage equations are:

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

and

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

ENDNOTES

1. For example, a regulation may require that no fugitive emissions escape from any flange or joint within the plant. To meet this regulation, a plant may need to train and hire additional personnel to constantly monitor these emissions.

2. The criteria air pollutants are sulfurous oxides, nitrous oxides, particulate matter, volatile organic compounds, ozone, and airborne lead.

3. Goodstein (1994) provides a survey of views on the tradeoff between jobs and the environment.

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

5. The EPA estimate of 2.1% is cited in Jaffe et al. (1995, 140).

6. The questionnaires that managers must answer to provide the data we use on abatement costs try to avoid this problem by asking respondents to classify all expenditures that they would not have made if no pollution regulations were in place as "PACE." Surveyors report that respondents find this approach confusing. To answer the question, many managers must imagine their production technology in a world without environmental regulation – a world that they are too young to have experienced.

7. Regulations generally either set standards or mandate emissions control equipment. PACE falls 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.

8. Here, we refer to "regulated" plants as those that face environmental regulations imposed by the SCAQMD and "unregulated" plants as those that do not face SCAQMD regulations.

9. By incremental risk of death we mean that, if the estimated risk of death given compliance with federal standards is n/10,000, the risk of death given noncompliance is (n + 1)/10,000. For comparison, the risk of death from an automobile accident in California is 2/10,000.

10. These estimates are based on value of life, contingent valuation, and hedonic studies that include measurements for increased mortality rates, reduced visibility, reduced activity days, and minor reduced activity days. The estimates do not include benefits from reduced levels of asthma, bronchitis, and angina; reduced hospital admissions or emergency room visits; or any other effects of toxic substances. Dollar figures are given in 1989 dollars.

11. Imputed plants account for approximately 2.2% of value added (Bureau of the Census 1991).

12. The 1983 plant-level PACE data were declared unusable by the Census Bureau in September 1995 due to quality control issues. No PACE survey was performed in 1987.

13. See Jaffe et al. (1995).

14. This logic applies only to plants remaining in the sample. Decisions to enter or exit the industry may be affected immediately by the adoption of new regulations.

15. There is further information that we are not yet making use of in order to keep the instrument set small. Much of the regulation of air quality falls into one of four categories, for each of three criterion pollutants. Most of the concern is with VOCs (volatile organic compounds), nitrous oxides, and sulfurous oxides. Regulations either (1) fix absolute levels of allowable emission ("emissions standards"), (2) explicitly require the installation of particular abatement equipment ("technology standards"), (3) require compliance with *either* an emission or a technology standard, or (4) do something more complicated (such as set a standard for the emissions *content* of *inputs*, as contrasted with emissions associated with *output*).

16. The reduced form in equation (2) in Appendix B is estimated as:

(2')
$$E_{it} = \delta_i + \phi_t + \mu R_{it} + \eta_{it},$$

assuming $E(R_{it}, \eta_{it}) = 0$ or,

(2'')
$$\Delta E_{it} = \Delta\phi_t + \mu\Delta R_{it} + \Delta\eta_{it},$$

assuming $E(\Delta R_{it}, \Delta\eta_{it}) = 0$ for $i = 1,...,N_t$ plants and $t = 1,...,T$ years.

Validity does not seem to be a serious issue in the case of regulations that set technology standards. We are reasonably confident that an explicit mandate precludes effects on labor demand, factor shares, or costs through any mechanism other than installation of the required technology. The instrument should therefore be uncorrelated with the error term (in a specification that includes a plant effect).

17. Regulation could induce entry of plants that produce abatement-producing equipment. However, none of the industries covered by the regulations we consider fall into that category.

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

19. 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.

20 . Input and output prices are available from the Census of Manufactures, every five years. This is the first attempt we know of to use these data to measure productivity while controlling for plant-specific price changes.

21. Liberally interpreted, these results provide evidence supporting the "Porter" hypothesis that constrained firms may be more profitable than unconstrained. Should this result hold up to further scrutiny, it would constitute the only evidence we know of that includes unconstrained comparison plants. The authors will conduct additional plant visits to investigate this anomaly further if the result holds true.

22. The bulk of the air pollution control policies in the SCAQMD target nitrous oxides (NOx), volatile organic compounds (VOCs), or sulfurous oxides (SOx). For example Rule 1105 limits the emissions levels of SOx emission from fluid catalytic cracking units. Rule 1176 is a technology standard, requiring replacement of sumps and wastewater separators with covered tanks and special mechanisms to reduce VOC emissions from the tanks.

23. In such instances, the polluter is given the option of either meeting a particular emissions standard or installing a given type of control technology. The level of emissions after the control technology is installed need not necessarily satisfy the otherwise applicable emissions standard.

24. 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 in California.

25. §40440.8(b)(1) requires that the SCAQMD determine the types of industries that will be affected by each of its rules or regulations.

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

27. A formal model is derived in Appendix C.

28 The general expectation is that environmental regulation leads to higher costs. This is interpreted as implying that regulation leads to higher *marginal* costs of production, which would imply that, as regulation increases, output should decline.

29. This assumption can be tested with data on input prices. We have not 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.

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