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How did air quality standards affect employment at US power plants? The importance of timing, geography, and stringency

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Abstract

We examine fossil-fuel power plant employment impacts of new nitrogen oxides (NOx) provisions under Title I of the 1990 Clean Air Act Amendments (CAAAs). These provisions required installation of reasonably available control technology (RACT) for NOx emissions for major stationary sources in the Ozone Transport Region and in more stringently classified ozone nonattainment areas. Standard approaches using nonattainment designation to identify regulatory impacts abstract from important implementation aspects such as when regulatory changes occur, where regulations are in effect, and which specific regulations apply. Omitting these factors can introduce bias by contaminating the control group, leading to underestimation of historical employment impacts and overestimation of projected impacts from tightening regulations. Our results indicate that the new NOx RACT requirements negatively impacted power plant employment. We find no significant impacts on generation, suggesting that installation of pollution controls may have contributed to labor-saving technical change at affected units.

Environmental regulation's potential impact on labor demand is of great importance to policy makers, but received relatively little attention from economists until the Great Recession. Through its impact on production costs and technology, changes in environmental regulation may shift economic activity, including jobs, within and across sectors. Resulting job displacement may have lasting economic and health impacts on workers (see, for example Jacobson, LaLonde and Sullivan, 1993; Sullivan and Von Wachter, 2009). Moreover, job loss in a particular sector can be relevant to the political economy of how policy is implemented (Joskow and Schmalensee, 1998). New Ozone National Ambient Air Quality Standards (NAAQS) are particularly salient due to high projected costs.[1] In 2011 the Obama administration took the unusual step of asking the EPA to withdraw its proposed rule to tighten the ozone standard, citing among other factors the

[1]The US EPA projected annualized costs of \$19-\$25 billion to reduce the ozone NAAQS from an average 8-hour concentration of 0.084 ppm to 0.070 ppm, the top of the range supported by Clean Air Scientific Advisory Committee (US EPA, 2008).

importance of reducing regulatory burdens as the economy recovered from the Great Recession.[2]

Our paper focuses on the effect of ozone regulations on employment in the power sector. The power sector is a significant source of nitrogen oxides (NOx), an important precursor to the formation of ozone. Consequently, the most direct impact of tightened ozone standards on the power sector is likely to be felt through NOx control requirements.[3]

Will more stringent regulations lead to plant closures and job loss? Or will installation and operation of pollution-control equipment create jobs? Perhaps environmental rules will cause firms to invest in productivity-enhancing upgrades that increase output while reducing employment? These questions require empirical analysis since stricter pollution control requirements have an ambiguous theoretical impact on output and input use in the directly regulated sector (Berman and Bui, 2001; Morgenstern, Pizer and Shih, 2002).[4]

Over the past two decades it has become common to use geographic heterogeneity in regulatory stringency mandated by the 1977 and 1990 Clean Air Act Amendments (CAAAs) as a quasi-experiment to test hypotheses regarding economic impacts of environmental regulation. In this framework, areas designated as attaining NAAQS serve as a control group with which to compare outcomes in more heavily regulated nonattainment areas. This approach has been used to study pollution levels (Henderson, 1996; Kahn, 1997; Greenstone, 2003, 2004; Au hammer, Bento and Lowe, 2009), housing prices (Chay and Greenstone, 2005), productivity (Greenstone, List and Syverson, 2012), county tax revenue (Carr, 2011), industrial sector diversity (Carr and Yan, 2012), investment decisions (Henderson, 1996; Becker and Henderson, 2000; List and McHone, 2000; List, McHone and Millimet, 2003; List et al., 2003; List, McHone and Millimet, 2004; List, Millimet and McHone, 2004; Becker, 2005; Condliffe and Morgan, 2009; Morgan and Condliffe, 2009), and employment (Greenstone, 2002; Kahn and Mansur, 2013; Walker, 2011, 2013).

The main contribution of our paper is to show the importance of incorporating a more nuanced measure of regulatory stringency than the simple attainment/nonattainment designation. Our work differs from previous research by focusing on the specific elements of NAAQS nonattainment status likely to affect employment decisions.[5] Specifically, our treatment variable reflects new provisions in the 1990 CAAAs requiring “reasonably available control technology” (RACT) for NOx emitters in more stringently regulated ozone NAAQS nonattainment areas. This focus highlights the importance of accounting for timing, geographic scope, and stringency of regulatory impacts that would be overlooked by a standard attainment/nonattainment identification strategy.

Regarding timing, although the 1990 CAAAs announced the general structure of the new NOx emissions controls, it was not until April 1992 that EPA first issued plans on how to

[2]https://obamawhitehouse.archives.gov/the-press-office/2011/09/02/statement-president-ozone-national-ambient-air-quality-standards
[3]Contol requirements are not set in the Clean Air Act itself, but through regulations promulgated to implement the statute.
[4]Examples of studies examining some of these issues include local air regulation in southern California (Berman and Bui, 2001), the EPA’s 1998 “Cluster Rule” for pulp and paper manufacturing (Gray et al., 2014), the Acid Rain SO_2 Trading Program (Ferris, Shadbegian and Wolverton, 2014), and the NOx Budget Trading Program (Curtis, forthcoming).
[5]Many federal requirements triggered by nonattainment apply to states or the transportation sector, not to industrial sources.

implement the 1990 CAAAs (57 FR 13498).[6] States were required to submit State Implementation Plan revisions by November 1992 with their NOx RACT rules for major stationary sources. To reflect this temporal aspect of the regulation we use an empirical specification that allows the regulatory impact to vary over time. Our main treatment period begins in 1993, once state NOx RACT regulations were required, but we also include a transition period from 1990–1992 to allow for possible anticipatory effects relative to the pre-treatment period of 1987–1989. In contrast, a specification assuming CAAA implementation only through ozone nonattainment designations, and not specifically through NOx RACT could erroneously regard as yet untreated plants (e.g., in ozone nonattainment areas prior to 1990) as being highly regulated.[7]

With respect to geographic scope, the literature typically assumes all polluting sources in attainment areas to be less regulated than similar plants in nonattainment areas. The 1990 CAAAs, however, established the Ozone Transport Region (OTR) in northeastern and mid-Atlantic states.[8] The entire OTR was subject to NOx RACT requirements, even if a county was technically in attainment with the ozone NAAQS (57 FR 55620). The standard approach, however, would count sources in attainment areas in the OTR as not highly regulated.[9]

Regarding stringency, previous literature focused on estimating impacts of NAAQS regulations using a binary nonattainment indicator for more stringent regulation. After the 1990 CAAAs, however, ozone nonattainment areas were divided into several classifications with differing levels of regulatory stringency. NOx RACT requirements applied only to power plants in Moderate, Serious, Severe, and Extreme classifications. The standard approach would risk counting untreated plants in nonattainment areas not subject to the NOx controls as highly regulated.[10]

To evaluate empirically the importance of these issues, we construct a power plant-level panel data set (1987–1998) which includes information on employment and power generation, along with county-level data on ozone regulatory status. This data set allows us to perform a difference-in-difference analysis comparing employment levels between power plants subject to NOx RACT and control plants in the transition period (1990–1992) and the treatment period (1993–1998) relative to the pre-treatment period (1987–1989). To identify the impact of NOx RACT on power plant employment we use a difference-in-differences approach with plant fixed effects, similar to previous studies evaluating nonattainment impacts (e.g., Walker, 2013).

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[6]Throughout the paper we use the standard abbreviation for *Federal Register* citations: [volume] FR [page number].
[7]Following the precedent of Greenstone (2002), several papers analyzing the pre-1990 period treat NOx emitters in ozone nonattainment areas as being highly regulated (Becker, 2005; Greenstone, List and Syverson, 2012; List, McHone and Millimet, 2003; List et al., 2003; List, McHone and Millimet, 2004; List, Millimet and McHone, 2004).
[8]The OTR comprises Maine, New Hampshire, Vermont, Massachusetts, Connecticut, Rhode Island, New York, New Jersey, Pennsylvania, Maryland, Delaware, the District of Columbia, and the northern counties of Virginia in the Washington, DC Consolidated MSA (42 USC §7511c(a)).
[9]Several studies of the post-1990 period do not treat attainment counties in the OTR as highly regulated (Carr, 2011; Carr and Yan, 2012; Condliffe and Morgan, 2009; Kahn and Mansur, 2013; Morgan and Condliffe, 2009; Walker, 2011, 2013). Curtis (forthcoming) does describe the OTR in the context of the NOx Budget Trading Program.
[10]None of the studies of the post-1990 period cited above consider the differential impact of ozone non-attainment classifications.

Our empirical work yields three main results. First, power plants in ozone nonattainment areas and in the OTR subject to the new NOx requirements experienced a significant relative decline in employment. This decline began after 1990, and became statistically significant after 1993. Second, a standard difference-indifference approach based on changes in nonattainment status would not detect these employment impacts since many plants subject to the new NOx RACT would effectively be placed in the control group. Third, while we find that the new NOx RACT regulations had a statistically significant negative impact on power plant employment, they did not have a statistically significant impact on generation. This finding suggests that the channel may have been labor-saving technological change rather than a loss in competitiveness.

Our findings are particularly important to help policymakers use historical results to evaluate the employment effects of future ozone regulations. Ozone NAAQS have been tightened twice in the past 20 years, with some areas previously in attainment redesignated as nonattainment. The 15 power plants in new nonattainment areas in 2012 were not distributed as they were in the 1990s. Specifically, in the 1990s there were 250 plants in ozone nonattainment or the OTR, of which 211 were subject to new NOx RACT regulation. In contrast, all 15 plants in newly designated nonattainment areas in 2012 were in Marginal classifications not subject to NOx RACT. Consequently, we find that using simple ozone nonattainment status could lead to an over-prediction of employment effects at power plants for new, tighter air quality standards. The standard attainment/nonattainment approach would predict a significant loss of approximately 430 jobs (95 percent confidence interval [−590, −265]), while an approach taking account of the difference in stringency among classifications would predict a nonsignificant loss of about 95 jobs (95 percent confidence interval [−535,+430]).

The remainder of the paper is organized as follows. Section I describes the historical policy context and institutional setting for the power sector during the study period and Section II provides intuition for how these policies might influence labor demand at affected facilities. We describe the data in Section III and develop the empirical methodology in Section IV. Results are presented in Section V, and Section VI concludes.

I. Major policy changes affecting electric power plants in the 1990s

During the 1990s power plants were subject to two major policy changes whose impacts varied geographically. With respect to environmental policy, the 1990 CAAAs required NOx controls for the first time for power plants in more-stringent ozone nonattainment areas and the OTR. Concurrently, many states began the process of restructuring their electricity markets to open regulated monopolies to greater competition, which previous research has found has a negative impact on employment (Fabrizio, Rose and Wolfram, 2007). In this section, we provide a brief overview of these policies.

A. Changes to power plant NOx requirements under the 1990 CAAAs

The 1990 CAAAs set the stage for NOx emission controls for power plants in ozone nonattainment areas. The legal term for the existing source control requirements is Reasonably Available Control Technology (RACT). Here, we provide details on what

constitutes NOx RACT, and statutory and regulatory changes during the 1990s that affected when and where power plants were subject to NOx RACT.[11]

RACT requires that major sources of a pollutant for which its area is out of attainment for a NAAQS have an emissions limit based on technological and economic feasibility (44 FR 53726).[12] RACT is not a specific pollution control retrofit or process requirement imposed by the EPA. Rather, states determine RACT on a case-by-case basis, taking into account such characteristics as a source's physical layout and cost per ton of emissions reduction relative to similar sources.

Ozone is unique inasmuch as while the NAAQS is set with respect to ambient ozone concentrations, emitting sources are defined on the basis of emissions of precursor pollutants, volatile organic compounds (VOCs) and NOx, that together form ozone. Before 1990, however, RACT requirements applied to major sources of VOCs, but not NOx. As a source category, fossil-fired power plants do not have VOC RACT requirements (57 FR 55620). Thus, even if a power plant were in an ozone nonattainment area throughout the 1980s and 1990s it would not have been subject to RACT for either pollutant before the 1990 CAAAs.

NOx RACT regulations for electricity generation units are generally written in the form of rate-based performance standards (e.g., tons of NOx emitted per unit of output).[13] A power plant typically complies with a standard by retrofitting with pollution control devices and/or changing production processes to reduce NOx formation. In most cases, the EPA believed NOx RACT emissions limits for utility boilers would be achievable by installing low-NOx burners (57 FR 55620, Sec. 4.6).

Although the 1990 CAAAs established the statutory framework for power plant NOx RACT requirements, it took a few years to promulgate the implementing regulations. The 1990 CAAAs mandated that states revise their Clean Air Act State Implementation Plans (SIPs) to incorporate NOx RACT limits by November 1992, with controls to be installed "as expeditiously as practicable but no later than May 31, 1995" (42 USC 7511a(b)).[14] To assist states in this process, in 1992 the EPA issued NOx emissions limits that it expected to satisfy RACT for several types of utility boilers. Our main specification reflects this timing by defining the main treatment period as 1993–1998, but it also includes a transition period from 1990–1992 to allow for anticipatory effects between the announcement of the general NOx RACT structure and state implementation.

Prior to 1990, states were responsible for designating areas whose ozone concentrations exceeded the NAAQS as simply being in nonattainment. Title I Subpart 2 of the 1990 CAAAs introduced five new classifications of ozone nonattainment increasing in stringency: Marginal, Moderate, Serious, Severe, and Extreme. The Act also defined Submarginal and

[11]For a more detailed treatment of NOx regulation, see Burtraw and Evans (2004).

[12]Major NOx sources typically emit more than 100 tons per year of the pollutant, although this threshold is reduced for more stringently classified ozone nonattainment areas.

[13]See, for example, 57 FR 55620.

[14]The 1990 CAAAs place the main responsibility for regulation with the states. States are required to prepare SIPs to demonstrate how they will comply with the Act's requirements. These SIPs must then be submitted for approval to the EPA.

Transitional areas that continued to be regulated under the pre-1990 VOC-only provisions of Subpart 1. After 1990, ozone nonattainment classification was based on ambient ozone pollution concentration from 1987–1989. Geographically, NOx RACT applies directly to plants in ozone nonattainment areas classified as Moderate or above. By extension, NOx RACT also applies to the entire OTR since it is regulated as if it were at least in Moderate ozone nonattainment (57 FR 55620, Sec. 2.2 and 2.3).

Being classified as a Marginal or Subpart 1 ozone nonattainment area did have some source-specific provisions: requirements for new sources,[15] emissions thresholds for being considered a major source, and/or record-keeping requirements (emissions statements). Since our data set only contains major sources and has few new entrants (only 9 power plants began operations between 1990 and 1998), we do not expect these other rules to substantially impact employment decisions.[16]

In summary, our focus on the NOx RACT regulations implementing Title 1 of the 1990 CAAAs marks a difference from the prior literature examining employment impacts of nonattainment status more generally (e.g., Greenstone, 2002; Kahn and Mansur, 2013; Walker, 2013). Our identification relies on the fact that federal NOx RACT requirements applied to all fossil-fuel fired power plants in the OTR (regardless of nonattainment status), and those in a subset of more-stringent ozone nonattainment classifications (Moderate and above). In terms of timing, although the 1990 CAAAs indicated NOx RACT was forthcoming, states were not required to revise their implementation plans until late 1992. Taken together, these issues regarding timing, stringency, and geography underscore the importance of using a sufficiently flexible econometric specification to identify the impacts of the environmental regulation.

B. Other relevant Clean Air Act Provisions

In addition to ozone, Title I of the Clean Air Act sets NAAQS for five other “criteria” pollutants: carbon monoxide, lead, nitrogen dioxide (NO_2), particulate matter (PM), and sulfur dioxide (SO_2). Of these, the three most relevant for power plants are PM, NO_2, and SO_2. Unlike the case with NOx, however, the 1990 CAAAs did not substantially change NAAQS nonattainment provisions for these pollutants from what was previously required (Wooley and Morss, 2012).

Independent of the NAAQS requirements stipulated in Title I, the acid rain provisions of Title IV of the 1990 CAAAs also regulated SO_2 and NOx emissions for a subset of coal-fired power plants (Ferris, Shadbegian and Wolverton, 2014). The SO_2 provisions established a flexible emissions trading program for affected facilities beginning in 1995. In contrast, beginning in 1996, the NOx provisions imposed plant-specific technology-based command and control emissions limits on affected facilities. These limits could typically be achieved with low-NOx burners.[17] Other federal NOx provisions such as the NOx Budget trading program occurred after our period of analysis.

[15]New NOx sources in Marginal and above ozone nonattainment areas have strict “Lowest Achievable Emission Rate” standards and must o set emissions with reductions at other sources in the same area.
[16]We include sensitivity checks to explicitly test these predictions.

C. Electricity Market Restructuring

During the 1990s many states began the process of liberalizing retail electricity markets. Earlier, most electricity was provided by vertically integrated utilities operating as monopolists. Local regulators set prices based on cost of service. This rate structure gave little incentive for plant managers to reduce cost.

By 2000, 26 states and the District of Columbia had passed legislation allowing competitive access of power generators to retail electricity markets. In these restructured areas prices would be set by market forces. Plant managers would thus have a greater incentive to cut costs and improve efficiency, particularly in investor-owned utilities (IOUs). Fabrizio, Rose and Wolfram (2007) find that anticipation of increased competition may have affected generator operating efficiency among privately owned utilities as early as the initiation of the public hearings that took place in the mid-1990s.

II. How might NOx RACT regulations affect employment?

Standard neoclassical labor demand theory indicates that environmental regulations may have different effects on labor demand (Berman and Bui, 2001). If regulatory compliance costs lead to increased production costs and a corresponding increase in output price, then reduced consumer demand could cause the producer to scale back production and labor inputs, holding the relative share of capital and labor constant (output effect). Depending on the approach used for reducing pollution, holding output constant, the relative share of capital and labor in production may shift from capital towards increased use of labor, or vice versa (substitution effect).

Generally, the output effect has a negative impact on labor demand except in the rare instance where regulation lowers marginal cost. The substitution effect is indeterminate and may depend on the methods used to reduce pollution. For example, end-of-pipe pollution abatement equipment can be added on at the end of the production process to remove pollution, and requires additional labor to operate and maintain that equipment. In contrast, "improvements in production process, such as the installation of more efficient boilers which operate at lower levels of emissions, often reduce demand for production workers due to a general skill-bias of technological change" (Berman and Bui, 2001, p.275). If power plants primarily chose end-of-pipe approaches to comply with NOx RACT, we might expect a positive substitution effect on relative demand for labor. If, however, power plants complied by means of efficiency-enhancing process changes we might find a negative substitution effect for labor demand. Overall, the net effect on labor demand is theoretically indeterminate and depends whether a negative output effect is larger than any positive substitution effect (Deschenes, 2014).

Given this theoretical ambiguity, our empirical analysis tests variations of the following questions. Do power plants facing more stringent environmental regulation decrease their labor demand relative to less regulated power plants, and if yes, how does this effect vary

[17] The EPA also allowed other more flexible compliance options, such as allowing utilities to reduce average NOx emissions across boilers, rather than requiring boiler-specific limits to be met. For more detail regarding Title IV, see US EPA (1997).

over time? How sensitive are these results to plant ownership type and changes in output price structure implied by anticipated deregulation of retail electricity markets? Finally, we explore possible mechanisms by which regulations might affect labor use. For example, if there was an employment effect of environmental regulation did it operate primarily through the output channel; i.e., did NOx RACT significantly affect electricity generation? Or did it operate via substitution, i.e., controlling for generation, how did labor demand change?

III. Data

Our data set, consisting of an unbalanced panel of 594 power plants from 1987–1998, yields 6,424 power-plant year observations. Plant-level data are drawn from Fabrizio, Rose and Wolfram (2007). This data set consists of plant operating characteristics from Federal Energy Regulatory Commission (FERC) Form 1 (investor-owned plants), Energy Information Agency (EIA) Forms 412 and 767 (municipally-owned plants), and Rural Utilities Service (RUS) Forms 7 and 12 (rural electric cooperatives) as compiled in the Utility Data Institute (UDI) O&M Production Cost Database. Variables include average number of employees, net MWh generation, installed MW capacity, plant age, North American Electric Reliability Corporation (NERC) region and dummies for primary fuel source (coal, gas, or oil).[18] Employment data may not include workers contracted to install pollution control equipment, however, so this potential regulatory impact may not be captured. Utility ownership type is from UDI's 1997 Datapak Book. Fabrizio, Rose and Wolfram (2007) also compiled utility wages, fuel expenses per BTU, and years in which states initiated electricity market restructuring hearings.

To the Fabrizio, Rose and Wolfram (2007) data we add county-level 1993 ozone nonattainment classification status, manually coded from 40 CFR 81.[19] This source does not include information on the OTR. Instead, we use the relevant section of the statute, 42 USC §7511c(a), to identify OTR areas. We then define a NOx RACT variable that equals one for ozone nonattainment areas classified Moderate or higher, and any areas within the OTR, and equals zero for areas outside of the OTR that are either ozone attainment, Subpart 1 nonattainment, or Marginal nonattainment.[20] Figure 1 illustrates location and treatment status for sample plants.[21]

The 1990 CAAAs classified ozone nonattainment status from Marginal up to Extreme. However, our sample only contains 11 plants (122 plant-year observations) located in Extreme ozone nonattainment areas, and these plants are quite different from the rest of our sample. Specifically, all 11 plants are older gas-fired plants located in counties in California's South Coast Air Quality Management District (SCAQMD) that, in addition to being in the only NO_2 nonattainment area, are also out of attainment with respect to PM and

[18]A small number of plant-years reported separate entries for different boilers. When this occurred we combined boiler data to create a single observation.

[19]The 1990 CAAAs designated most areas, but states had time to challenge some designations and submit area boundary adjustments. Almost all these issues were resolved by 1993.

[20]Subpart 1 refers to all areas regulated under the pre-1990 ozone rules. The statute lists these areas as Transitional, Sub-Marginal, and Incomplete Data.

[21]To construct the map, we geocode plants using EPA's Emissions and Generation Resource Integrated Database (eGRID), available at http://www.epa.gov/cleanenergy/energy-resources/egrid.

SO_2 NAAQS.[22] Moreover, counties in the SQAQMD were subject to distinct NOx regulations that changed during our sample period.[23] We therefore created a “South Coast” dummy to allow us to control for the unique circumstances of these plants.

In addition to the NOx RACT treatment, we include data for other selected 1990 CAAA provisions affecting power plants: specifically PM and SO_2 nonattainment status, and the NOx provisions of the Title IV Acid Rain Program. County nonattainment status data for these criteria pollutants comes from the EPA’s Green Book.[24] Plant years affected by Title IV provisions come from the EPA’s compliance website.[25]

Table 1 presents summary statistics for the pre-treatment period preceding the 1990 CAAAs.[26] The first column is the treatment group, power plants in areas (Moderate and above ozone nonattainment and the OTR) subject to the new NOx RACT requirements. The second column is our control group, all other plants. The last column presents differences and *t* statistics between treatment and control groups. Panel (a) contains means of within-plant means over the 1987–1989 pre-treatment period. Panel (b) presents means of within-plant differences from 1987–1989.

We find significant differences between treatment and control plants with respect to ownership status (investor vs. municipal or cooperative-ownership), location in states that eventually restructured their electricity markets, fuel type, attainment status for other NAAQS criteria pollutants that require power plant pollution controls (SO_2 and PM), Title IV NOx, and age. The main analysis uses several types of controls to more precisely identify the impact of NOx RACT, rather than any potential confounding effects from these observable differences. We also conduct several robustness checks detailed in Section V.D to ensure our main results are not sensitive to alternative specifications.

IV. Empirical Methodology

Similar to Greenstone (2002) and Walker (2013) our main results use a difference-in-difference approach to identify the impact of environmental regulation on employment.[27] A key divergence between our approach and earlier studies lies with the definition of the treatment group. Whereas standard practice in the literature is to use changes in nonattainment status to identify the regulatory impact, we use change in NOx RACT status (i.e., whether a plant was in the OTR or a Moderate or above ozone nonattainment area as of 1993).[28]

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[22] NO_2 is a type of NOx and uses similar pollution controls.

[23] For example, electricity generating facilities in SCAQMD participated the Regional Clean Air Incentives Market from 1994–2001, allowing them to engage in emissions trading as an alternative to command and control NOx regulation (Fowlie, Holland and Mansur, 2012).

[24] Nonattainment data files phistory.xls and phisttsp.xls are available from www.epa.gov/airquality/greenbook/data_download.html.

[25] ftp://ftp.epa.gov/dmdnload/compliance/

[26] Some plants have missing data in the years appearing in this table. For the entire panel, there are 211 treatment plants (2,251 plant years) and 383 control plants (4,173 plant years).

[27] Some studies estimate a third difference by distinguishing between polluting and and non-polluting manufacturers in the same county. Unfortunately, this distinction cannot be made precisely. Using an industrial classification’s pollution intensity (e.g., Becker and Henderson, 2000; Greenstone, 2002) can result in mischaracterization of large individual polluters in low emission sectors and vice versa. Using the EPA’s Air Facility Subsystem (AFS) permit database (e.g., Walker, 2011, 2013) runs into similar issues since it only provides a current snapshot of permitted facilities, not a historic archive. Here, we gain precision in the definition of treated plants at the expense of being unable to estimate a third difference.

Treatment, D_i, takes a value of 1 if plant i is located in a county affected by NOx RACT in 1993, else it is zero. $Y_{it}(1)$ and $Y_{it}(0)$ denote the log employment for plant i in time period t, conditional on being treated or not. We estimate the average treatment effect on the treated (ATT):

$$ATT_t = E\left[\left[Y_{it}(1) - Y_{it}(0)\right] \middle| D_i = 1, \mathbf{z}_{it}, \gamma_i\right]. \quad (1)$$

Here γ_i is a plant fixed effect and z_{it} is a vector of control variables (including time fixed effects) discussed in detail below. ATT_t represents average difference in outcomes between treated plants in period t, relative to the counterfactual case in which they were untreated. Since the counterfactual is unobservable, we use outcomes for plants in counties not subject to NOx RACT as of 1993, assuming

$$E\left[Y_{it}(0) \middle| D_i = 1, \mathbf{z}_{it}, \gamma_i\right] = E\left[Y_{it}(0) \middle| D_i = 0, \mathbf{z}_{it}, \gamma_i\right]. \quad (2)$$

We implement this model using the regression

$$Y_{it} = \sum_{\tau = 1, \tau \neq t_0}^{T} \beta_\tau \left[D_i \times 1(t = \tau)\right] + \alpha \mathbf{z}_{it} + \gamma_i + \epsilon_{it}, \quad (3)$$

in which $\in_{it}$ is an error term. We cluster standard errors by state to allow for arbitrary correlation of error terms across plants regulated by the same state environmental agency.

Our main specification sets $T = 3$, using the pre-treatment period (1987–1989) as the base. The second, transition, period (1990–1992), falls between the 1990 CAAAs enactment and the EPA's announcement of the new NOx RACT SIP expectations, and the final period is our treatment period (1993–1998). County regulatory status is interacted with an indicator variable equal to one if τ is period t, omitting the base period t_0.[29] This interaction allows us to flexibly identify time-varying effects of 1993 regulatory status.

The β_t parameters indicate the approximate percentage change in our outcome variables caused by implementation of NOx RACT regulations in each period (relative to the omitted base period) relative to the control group.[30] A value of 0.03 for β_3, for example, would indicate that the difference in outcomes in the 1993–1998 period relative to the 1987–1989 period was approximately three percentage points higher for a power plant subject to NOx RACT relative to a control plant.

[28]The EPA promulgated regulations with most official ozone nonattainment designations in November of 1991. Due to border adjustments some ozone nonattainment areas were not officially designated until 1993. We base our treatment on plant county status as of this date.

[29]The base period parameter cannot be identified due to time effects.

[30]Since the outcome uses a log transformation, we use $[e^x - 1] * 100$ to approximate the percent impact implied by parameter value x.

The difference-in-difference approach relies on a parallel trends assumption that employment in control and treatment plants would have followed a similar path but for the regulation. While it is not possible to test this counterfactual for the post-treatment period, Panel (b) of Table 1 suggests that there are no significant differences in the changes in key variables between the treatment and control groups in the 1987–1989 pre-treatment period. As further evidence supporting the parallel trends assumption, Figure 2 shows the time path of mean of log employment for treatment and control groups. The paths are roughly parallel in the 1987–1989 pre-treatment period.[31]

As shown in Table 1, there are significant differences in observables between our treatment and control groups. Our main specification uses a combination of fixed effects and control variables to reduce the potential for these differences to bias our results.

Plant-level fixed effects control for time-invariant differences across plants such as location and plant average pre-treatment (1987–1989) emissions levels. The key identifying assumption in the difference-in-differences approach is that employment in control and treatment plants would have followed a similar path but for the regulation. Table 1 Panel (b) indicates that there are parallel trends prior to the policy. Our parallel trends identification assumption may be violated, however, if there are unobserved time-varying plant characteristics correlated with NOx RACT that also affect employment. Although we cannot control for such unobservable plant-specific time-varying characteristics, to reduce the threat of this type of bias we introduce several observable time-varying controls. In addition, the regulatory structure of the 1990 CAAAs introduced changes, and specifically changes in implementing regulations, such as NOx RACT, that were not driven by changes in local air quality, local economic growth, or employment. This regulatory structure provides a rich source of identifying variation for examining such impacts (Walker, 2013).

As illustrated in Appendix Figure A1, NERC divided the continental U.S. wholesale electricity market into ten regions tasked with managing local markets for reliability purposes. Interacting a dummy for fuel type with NERC region and yearly fixed effects flexibly controls for trends that may be influenced by unobserved local factors such as input prices, fuel transportation costs, and other time-varying demand or supply shocks.

Although NAAQS nonattainment area requirements for sources of SO_2 and PM_{10} did not change in the 1990s, it may be the case that plants subject to these NAAQS affecting electricity generators behaved differently over time from those that did not. To control for this possible effect we interact “PM or SO_2 nonattainment” (a dummy for plants in a nonattainment county for either of these pollutants as of 1993) with a dummy for each time period.

[31]Figure 2 does not condition on plant characteristics. Appendix Table A1 presents a variation of our main regression to test the hypothesis that treated plants had different employment paths pre-treatment. Non-zero values for the NOx RACT parameters could suggest a possible divergence in pre-treatment outcomes between control and treatment groups. Parameter values, however, are close to zero and statistically insignificant.

Plants subject to NOx RACT were significantly less likely to be affected by the Title IV Acid Rain Program's NOx provisions. We include a dummy variable to control for affected plant-years to avoid confounding its effects with NOx RACT.[32]

Due to their different incentive structure, investor-owned utilities (IOUs) may respond to unobserved shocks differently than publicly owned utilities (Fabrizio, Rose and Wolfram, 2007). We interact a dummy for ownership status ("Muni" for non-IOUs) with time-period dummies to control for this potential effect. Moreover, Fabrizio, Rose and Wolfram (2007) find IOUs in restructuring states had a significant drop over time in labor conditional on output. We control for this potential impact with a time-varying dummy "Restructured" for IOUs in states that restructure their electricity market. Following Fabrizio, Rose and Wolfram (2007), this dummy takes a value of unity after the initiation of public hearings on restructuring.

As noted by Walker (2013), Chay and Greenstone (2003), List et al. (2003), a possible correlation between pollution and unobserved economic activity may pose a problem for identifying effects of environmental regulation. The concern would be that unobserved local economic growth caused a change in pollution, and this change in pollution caused the plant to be subject to NOx RACT. If economic growth also causes an increase in power plant employment one would risk falsely attributing increased employment to environmental regulation.[33] This issue is unlikely to jeopardize our identification strategy for the same reasons identified by Walker (2013); exogenous statutory changes in the 1990 CAAAs, combined with historic pre-treatment (1987–1989) air quality levels, not changes in air quality, determined whether plants became subject to NOx RACT.

V. Results

We present three sets of results. The first shows the time-varying employment impact of the new NOx RACT requirements on fossil-fueled power plant employment. The second highlights the importance of accounting for changes in regulatory status over time, space, and stringency for historic and future regulatory analysis. The third explores mechanisms by which NOx RACT may have impacted employment decisions at power plants during this period.

A. NOx RACT employment impacts

Column (1) in Table 2 presents the main results. Parameter values for NOx RACT represent the difference between treatment and control plants in the difference in log employment between the respective time periods and the omitted 1987–1989 base period. Consistent with the stylized facts of 1990 CAAA implementation described in Section I, plants affected by NOx RACT performed differently from control plants, with the most pronounced impact following the 1992 state regulatory deadline. Overall, employment in these plants during the 1993–1998 period was approximately 13 percent lower than control plants, relative to the

[32]An alternative specification, available upon request, adds controls for plant-years affected by the Title IV SO_2 emissions trading program. NOx RACT results are not sensitive to inclusion of this dummy.

[33]Note the importance of changes in pollution causing a change in regulatory status. Plant fixed effects should control for unobserved correlations between pre-treatment pollution levels and economic activity.

1987–1989 pre-treatment period. If there was a response after the passage of the CAAAs in anticipation of forthcoming regulation, it was relatively small, 3 percent, and not statistically significant. Other CAA provisions such as being located in a PM or SO_2 nonattainment area or being subject to Title IV NOx provisions did not have significant impacts.[34] Apart from the NOx rules, the other main driver of employment was ownership status. Relative to the 1987–1989 base period, investor-owned utilities had significantly lower employment than their municipally or cooperatively owned peers.

B. Timing, geography, and stringency

To identify the employment impacts of environmental regulation, our main analysis focused on implementation of NOx RACT for power plants. The literature typically abstracts from this level of detail, focusing instead on ozone nonattainment designation. In this section, we highlight the potential benefits of focusing on an implementing regulation. To do so, we change the definition of treatment from NOx RACT to ozone nonattainment. This change has three implications. Regarding timing, the majority of power plants' ozone nonattainment status did not change from 1987–1998. Geographically, the literature has not typically included plants in attainment areas in the OTR within the treatment group despite OTR areas being more stringently regulated. Regarding stringency, by focusing only on ozone nonattainment status the literature typically treats plants in ozone nonattainment areas equally in terms of ozone regulations, despite the fact that the 1990 CAAAs introduced a range of increasingly-stringent ozone nonattainment classifications, from Marginal to Extreme, and in our specific case, only power plants in Moderate and above ozone nonattainment areas and in the OTR were subject to NOx RACT.

Model (1) of Table 3 presents results analogous to a standard difference-in-difference estimator in which the effect of ozone nonattainment is assumed to be time invariant. The treatment, "New O_3" refers to plants in counties that switch from attainment to nonattainment.[35] This specification does not show any significant employment impact of ozone nonattainment. Model (2) treats plants in attainment areas in the OTR as nonattainment, while maintaining the assumption of time invariant treatment effects. Results are similar to Model (1). Model (3) uses the same categorization as Model (2), but relaxes the assumption of time invariant effects. In this model, ozone nonattainment status, "All O_3", is interacted with time period dummies, moving plants always in ozone nonattainment from the control group to the treatment group. Here, the significant impact of ozone nonattainment becomes evident in the post-1993 period (approximately −11 percent).

Figure 3 illustrates Models (1)–(3) of Table 6 using yearly interactions for the treatment (omitting 1990), rather than the multi-year periods used in the main specification. Panel (a) uses the treatment group in Model (1); only plants that switch attainment status ignoring the OTR are treated. Panel (b) uses the Model (2) treatment, moving plants in OTR attainment areas out of the control group. Panel (c) uses the Model (3) treatment group; all plants in

[34]These Title IV results are consistent with findings by Ferris, Shadbegian and Wolverton (2014).

[35]Inclusion of power plant fixed effects implies that treatment impacts are identified only by power plants in counties that change nonattainment status; plants that are always in nonattainment are effectively placed in the control group. This approach was used by Walker (2013), for example.

ozone nonattainment areas including the OTR are treated. Placing nonattainment plants in the control group as in Panel (a) masks the effect of the ozone regulations. As shown in Panel (b), plants in the OTR attainment areas are not driving this result. Only in Panel (c) does the treatment effect become apparent, particularly after 1992.

Model (3) of Table 3 can be misleading, however, inasmuch as it does not account for differences in stringency within ozone nonattainment areas. Model (4) divides plants into two distinct treatment groups, those subject to NOx RACT and those in other ozone nonattainment areas, Subpart 1 and Marginal, not subject to NOx RACT.[36] For this regression the control group contains only plants in ozone attainment areas outside the OTR.[37] These results provide support for our main specification that places the latter plants in the control group: only facilities in areas subject to NOx RACT have significantly different employment impacts from those in attainment areas.

Figure 4 illustrates the importance of allowing for differential impacts of stringency. Each panel contains an interaction of ozone classification with year effects, omitting 1990.[38] Plants in Subpart 1 and Marginal areas do not have significant employment impacts over time. Plants in Moderate and Serious areas, in contrast, exhibit significant declines in employment, particularly after 1992. Severe and Extreme areas show a similar pattern, albeit at a weaker level of significance.[39] Taken together, this evidence suggests a nuanced relationship between regulatory stringency and employment; only plants in those areas subject to the new NOx RACT requirements appear to respond to the 1990 changes to the Clean Air Act by significantly reducing employment.[40]

To illustrate the importance of accounting for differences in stringency we conduct an exercise predicting the impact of a change in designations on our sample. The ozone NAAQS has been revised twice after 1998. The most recent revision, in 2008, tightened the previous standard promulgated in 1997.[41] Designations under the 2008 standard were finalized in 2012. 48 counties previously in attainment were newly designated as nonattainment. Of these 46 were classified as Marginal and 2 were classified as Moderate. In our sample 15 plants were located in these newly designated ozone NAAQS nonattainment areas, all of which were classified as Marginal.

Figure 5 presents two back of the envelope predictions of the new designations' employment impact. Panel (a) uses estimates from Figure 3(c) that do not distinguish between ozone classifications. They predict a significant relative decline in employment reaching about 430 employees eight years after finalizing the standard. In contrast Panel (b), using coefficients specific for Marginal areas from Figure 4(b), shows no significant impact.

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[36] There are 39 plants (420 plant years) in the "Other O_3" category.

[37] Appendix Table A2 presents summary statistics for the two treatments, NOx RACT and Other O_3, and controls (Attainment). Appendix Figure A2 presents employment trends for the control group and both treatment groups. The parallel trend assumption does not appear to be violated for either treatment group in the 1987–1989 pretreatment period.

[38] Plants (and plant years) for each classification are Attainment: 344 (3,753); Subpart 1: 23 (251); Marginal: 16 (169); Moderate 94 (998), Serious 31 (325), Severe 75 (806), Extreme 11 (122).

[39] Results for Extreme plants should be interpreted with caution since we are unable to control for the possible confounding effects of being in California's South Coast Air Quality Management District.

[40] The lack of significant impacts before 1990 for any treatment group lends further support to the parallel trends assumption.

[41] Designations for the 1997 ozone standard did not take place until 2002.

These results illustrate how prospective employment analyses can be sensitive to modeling regulatory stringency. The estimated impact for nonattainment designation should roughly correspond to the average impact across the various ozone classifications for the years in the sample. However, using the nonattainment designation parameter to evaluate a rulemaking that causes a different distribution of ozone classifications than those in the 1990s can introduce substantial bias. For the case of the 2008 ozone NAAQS considered here, using the binary nonattainment designation parameter rather than the classification parameters would result in a significant over-estimate of job loss since none of the affected plants were subject to NOx RACT.

C. Possible mechanisms

Results in Section V.A suggest that the NOx RACT requirements generally caused a decline in plant employment relative to attainment areas. In principle, the reduction in employment could occur through two channels. Pollution control requirements could increase marginal costs. During the mid-1990s electricity markets were being restructured in many states, opening them to increased competition. An increase in marginal costs could cause a nonattainment plant to drop in the dispatch order causing a reduction in generation and employment.[42] Alternatively, plants may have upgraded technology while installing NOx controls, reducing both emissions and labor requirements per MWh generation.[43] If they did, that might explain the relatively high labor impacts despite the low cost of typical controls like low-NOx burners.

If generation displacement occurred from treatment to control plants, and plant employment were positively correlated with generation, then estimates from the previous sections could exaggerate net national employment impacts of environmental regulation. In such a case, control plants would produce more electricity if regulated plants were treated than if they were not. If total generation remained unchanged then the decrease in generation in regulated plants, and any associated labor differential, could effectively be counted twice.

To consider the question of how environmental regulation affected employment, we consider net generation (log MWh) as a dependent variable in Eq. (3).[44] Model (2) of Table 2 suggests that such spillovers are unlikely to be driving employment results. While negative, generation impacts of NOx RACT are small in magnitude and statistically insignificant for both periods. This disconnect between generation and employment reduces concerns that spillovers in electricity markets bias estimated employment impacts. It suggests environmental regulation may have affected employment not by reducing output, but perhaps by inducing firms to change their production technology in a way affecting labor intensity.

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[42]Changes in marginal costs may not exert a strong effect on output decisions if demand curves are sufficiently inelastic (due, for example, to electricity market regulation or if the increase in cost is insufficient to change a plant's merit order in the dispatch curve).

[43]Swift (2001) provides anecdotal evidence that power plants may have responded to the Title IV NOx requirements by introducing efficiency-enhancing process changes. Unfortunately neither the Pollution Abatement Cost Expenditures Survey nor eGRID database contain either pollution control or emissions data over a time period that would allow us to evaluate this mechanism empirically.

[44]As shown in Table 1, similar to the case for employment, there do not appear to be significant pre-treatment differences in generation between control and treatment groups.

Pollution control retrofits may involve engineering studies and plant shutdowns. One mechanism by which a reduction in labor intensity might occur would be if plant managers took advantage of these sunk engineering and shutdown costs to design and install upgrades that would not have otherwise been economical. If these upgrades lowered labor intensity (e.g., through reduced maintenance) they may have led to reduced employment relative to unregulated plants.[45]

Given the general pattern of reduced employment during the 1990s shown in Figure 2, it is possible that environmental regulation affected employment by accelerating a trend of reduced labor demand that was taking place across the sector. To explore this mechanism, we modify our previous labor regressions to also control for changes in output. Similar to Fabrizio, Rose and Wolfram (2007), we include net generation as an explanatory variable for labor use. Recognizing its endogeneity as a choice variable, we use their strategy of using state-level electricity demand as an instrument. We also adopt their method of using by plant-epoch fixed effects to control for changes in plant capacity.[46]

Table 4 reports changes in labor conditional on generation, rather than overall labor demand. Model (1) presents OLS results, while Model (2) uses state sales as an instrument for net generation.[47] Overall results are consistent with the hypothesis that environmental regulation reduced labor use operating through the channel of reduced labor intensity. There is a statistically significant reduction in labor use (controlling for output and capacity) of approximately 12 percent for plants affected by the NOx RACT treatment.

D. Robustness Checks

Our main model is relatively parsimonious. In this section, we explore a variety of checks to ensure that results are robust to alternative specifications.

Summary statistics in Table 1 reveal significant differences between attainment and nonattainment areas for several covariates. This lack of balance has the potential to cause a misattribution of ozone regulation impacts. Fabrizio, Rose and Wolfram (2007) and Fowlie (2010), for example, find evidence suggesting IOUs in states facing market restructuring had different incentives regarding input use, including employment. Of particular concern is the fact that Fabrizio, Rose and Wolfram (2007) find IOUs in restructuring states had a significant drop in labor use conditional on output.

Appendix Figure A3 depicts states that initiated restructuring hearings between 1993 and 1998 that eventually restructured their markets.[48] Comparing this map with Figure 1 shows the overlap between market restructuring and NOx RACT requirements. From Table 1, treatment plants were over twice as likely to be IOUs in restructuring states than control plants.[49] It is possible that estimated NOx RACT employment impacts could be driven by

[45]Gray and Shadbegian (1998) identify a similar phenomenon in the pulp and paper sector, finding a significant relationship between productive (non-abatement) investment and the amount and timing of pollution control investment.
[46]A plant epoch is years over which capacity changes are less than 40 MW or 15 percent.
[47]First-stage regression results with log net generation as dependent variable are presented in Appendix Table A3. In the first stage, the excluded instrument, annual state electricity sales, has the expected statistically significant positive effect on plant-level net generation.
[48]The earliest hearings recorded in the Fabrizio, Rose and Wolfram (2007) data began in 1993.

plants affected by restructuring or other factors such as being in nonattainment for another pollutant, or plant entry and exit. We address this type of concern in several ways.

Difference-in-differences estimation is most appropriate when treatment–in our case being subject to the NOx RACT requirements–is randomly assigned. RACT requirements were not randomly imposed, however. Since the control group plants are not similar to the treated plants based on average observable characteristics, this non-random assignment may bias our main difference-in-differences results in Model (1) of Table 2. We approximate a randomized experiment by selecting a properly matched control group to eliminate or reduce this potential bias (Rubin, 2008). To get approximately unbiased estimates we need a control group that is not systematically different from plants subject to NOx RACT (Stuart and Rubin, 2008). We use propensity score matching (as developed by Rosenbaum and Rubin, 1983) based on pre-1990 attributes–excluding the outcome variable–to select a statistically similar control group from nontreated plants.[50]

To construct our control group we use nearest neighbor matching with replacement.[51] Performing matching with replacement comes with the potential cost of losing precision in coefficient estimation due to having fewer matched control plants (the number of plants in the regression drops from 594 to 299), however this approach also reduces potential bias by generating close matches between treated and control plants based on pre-policy characteristics (Stuart and Rubin, 2008). After obtaining our suitably matched control group, we use difference-in-differences estimation to investigate how NOx RACT affected employment relative to this matched control group. Matched regression estimates and standard errors, reported in Model (1) in Table 5, are close to the main estimates, suggesting pre-NOx RACT differences between our treated and non-treated plants are not driving results.

Next we consider the potential for market structure to affect our results. Model (2) of Table 5 includes an interaction of non-IOU (“Muni”) plant ownership and the NOx RACT treatment period. If ownership were driving results we would expect the NOx RACT treatment parameter estimate to be sensitive to inclusion of this interaction term. Model (3) is a similar specification with the interaction term being Restructured×NOx RACT×period. For both models, the interaction terms are not significantly different from zero. Moreover the point estimates and standard errors of the NOx RACT parameters without the interaction terms are close to those of our main results in Model (1) of Table 2. It is thus unlikely that either of these factors affects our results.

Model (4) of Table 5 presents a similar exercise to examine whether employment impacts are driven by nonattainment with PM or SO_2 NAAQS. The estimates and standard errors for NOx RACT are again similar to the main results.

[49]This difference is statistically significant at the 99 percent level.

[50]We also require plants in the matched control group to have common support, such that areas of the covariate space includes both treated and control units. Only regressions over areas with common support result in more robust statistical inference (Stuart and Rubin, 2008).

[51]We match treatment and control plants using psmatch2 (Leuven and Sianesi, 2003) in Stata. Attempts to use matching without replacement to increase precision by augmenting the number of matched plants in the control group were unsuccessful due to lack of balance between treatment and control groups in this case.

In theory, input prices may impact labor decisions made at power plants. Due to lack of high-quality input price data for all plants in our sample, and the possibility that plant-level input prices may be endogenous, we do not directly control for these prices in our main specification.[52] To evaluate the possible influence of input prices Model (5) uses state utility proxy wage data from and expenditures per heat input to control for prices.[53] In doing so, we lose 102 plant-year observations, but our main point estimates and standard errors remain largely unaffected.

The next two models explore how missing data might affect results. The main results drop missing plant-years from the regression. This approach may under-state (in absolute value) labor impacts if regulations cause plant exit or deter plant entry. For possible exits, we identify plants with missing data in years consecutive to 1998. We classify a plant as a "potential exit" if it has zero, negative, or missing net generation in EPA's eGRID for the years missing from the Fabrizio, Rose and Wolfram (2007) data.[54] Only 1 plant (7 plant-years), in a Moderate ozone nonattainment area, falls into this category.

Missing values might also correspond to new plants entering the sample after 1987. We define "potential entries" as plants with missing values consecutive to 1987 for which the first non-missing value reports plant age as being zero or one. Over the 12-year panel, 11 plants (64 missing plant-years) are potential entrants. Table 6 summarizes potential plant entry and exit.

As a conservative approach, Model (6) imputes a single worker for each missing plant-year corresponding to potential entry and exit.[55] To evaluate the degree to which (apart from entry or exit) plants with missing data may be driving results, Model (7) includes only those plants with no missing observations. Parameters from both models are generally similar to the main results, although imputing extremely low employment values for potential entries and exits reduces the precision of the estimates and overall fit of the model (R^2 drops to 0.18).

To summarize, the NOx RACT provisions apply to plants in moderate and above ozone nonattainment areas and the OTR. Our difference-in-difference strategy could be biased if there were unobserved time-varying conditions correlated with employment during the same period that affected either the power plants subject to NOx RACT, or the control group. While it is impossible to control for unobservable factors, to partially address this threat we conducted a battery of robustness checks to determine whether observable contemporaneous environmental or electricity market regulatory conditions affect our main NOx RACT results.

The same counties subject to NOx RACT were indeed subject to other CAAA Title I ozone nonattainment requirements, but these either affected the transportation sector or were minor reporting provisions. They are therefore unlikely to drive power plant behavior. Other 1990

[52]Fuel×region×year fixed effects should absorb common input price shocks at the NERC-region level.
[53]These data come from Fabrizio, Rose and Wolfram (2007) and the EIA.
[54]The eGRID database begins in 1996 and does not contain employment data.
[55]It is unclear what the actual employment was in these plants since some workers may have been used to construct or maintain a facility while it was out of use either prior to entry or post exit.

CAAA provisions that could potentially affect power plants in this period are the Title I requirements pertaining to SO_2 and PM nonattainment areas, Subpart 1 and Marginal ozone nonattainment areas, and the Title IV Acid Rain Program.

Model (4) of Table 3 explores whether ozone nonattainment itself had an impact independent of the NOx RACT provisions by introducing a time-varying dummy for plants in Subpart 1 and Marginal ozone nonattainment areas that were not subject to NOx RACT.

We explicitly control for time-varying impacts of SO_2 and PM nonattainment and the Title IV NOx acid rain provisions in our main specification. Model (4) of Table 5 further explores the possibility of an interactive effect between SO_2 and PM nonattainment and NOx RACT.

Several states began the process of restructuring their electricity markets during our period of analysis. Moreover, there was significant overlap between plants affected by restructuring and NOx RACT. We explicitly account for investor-owned plants affected by restructuring in the main specification, and Models (2) and (3) of Table 5 examine the possibility of an interactive effect between plant ownership or restructuring and NOx RACT.

Evidence from these robustness checks does not support the hypothesis that the main impacts of NOx RACT requirements on employment reported in Table 2 are caused by pre-regulatory systematic differences in our treatment and control plants, plant ownership type, electricity market restructuring, other 1990 CAAA provisions, plant entry and exit, or missing data. Point estimates for NOx RACT×time treatments are consistent across specifications: NOx RACT plants have a range of −0.01 to −0.04 in the 1990–92 period (compared with −0.03) and a significant range of −0.11 to −0.16 from 1993–98 (compared with −0.13).

VI. Conclusion

We examine three aspects of the 1990 Clean Air Act Amendments that may affect the estimated impacts of environmental regulations: timing, geographic coverage, and stringency of the requirements. Specifically, we analyze how the 1990 change in requirements for sources of NOx emissions in more stringent ozone nonattainment areas and the Ozone Transport Region affected employment at fossil-fuel fired power plants. In periods of low economic growth policy makers and the general public are interested in the potential impact of environmental regulation on output and employment. Due to its role as a major source of pollutants and in providing an essential input to other industrial sectors, impacts on the electricity sector are of particular importance.

In our models that use the standard approach of identifying employment impacts only from plants that switch attainment status we find no significant impact of ozone regulations from the 1990 CAAAs on employment. On the other hand, focusing on time-varying impacts of nonattainment regulation permits us to identify impacts on all affected plants, suggesting that new NOx RACT rules reduced employment. Moreover, we find that significant negative employment impacts after 1993 are limited to areas subject to the new NOx RACT requirements; ozone nonattainment areas not affected by these requirements show no significant downward trends in power plant employment.

This latter set of results is important for using historical experience with clean air regulation to analyze potential new policies. An analysis of the 2008 ozone NAAQS based on the standard binary attainment/nonattainment designation would lead to a significant over-estimate (in absolute value) of negative relative employment effects due to the fact that only 2 of the 48 newly designated nonattainment areas for that rule are subject to NOx RACT.

The most direct mechanism by which regulations might affect employment is by raising marginal production costs, inducing regulated plants to produce less output and therefore use fewer inputs, including labor. However, we find that the new regulations cause a decline in employment without a corresponding significant decline in generation, even controlling for electricity market restructuring taking place during this period. This outcome suggests that plant managers may have undertaken efficiency-enhancing process changes to reduce emissions or taken advantage of the shutdown period and engineering evaluations necessary for retrofitting pollution controls to perform unrelated efficiency upgrades to the facility. Results from a model showing a drop in employment conditional on generation are consistent with this channel.

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Appendix

Table A1—

NOx RACT impact on employment and generation, pre-treatment

Dependent Variable:	ln(employment) (1)	ln(MWh) (2)
NOx RACT × 1988	−0.006 (0.012)	−0.021 (0.042)
NOx RACT × 1989	0.003 (0.015)	−0.045 (0.069)
PM or SO_2 nonattainment × 1988	−0.024* (0.012)	−0.060 (0.056)
PM or SO_2 nonattainment × 1989	−0.020 (0.017)	−0.040 (0.075)
South Coast × 1988	0.108** (0.050)	0.051 (0.091)
South Coast × 1989	0.015 (0.034)	−0.118 (0.289)
Muni × 1988	0.028*** (0.006)	−0.046 (0.038)
Muni × 1989	0.052*** (0.010)	−0.048 (0.051)
Plant F.E.	Yes	Yes
Region × Year × Fuel F.E.	Yes	Yes
R^2	0.141	0.236
Plant-years	1615	1615
Plants	558	558

Note: Impacts are relative to plants not subject to NOx RACT. 1987 base period impact omitted. NOx RACT refers to plants in the OTR and ozone nonattainment areas (Moderate and above) subject to this regulation. South Coast is a dummy

for plants located in California's South Coast Air Quality Monitoring District. PM or SO_2 is a dummy for plants in nonattainment areas for either pollutant. Restructured is a dummy for IOUs in states that restructured electricity markets; it takes a value of unity after initiation of public hearings. Muni is a dummy for plants that are not investor-owned. Title IV NOx is a dummy for plant-years subject to the Acid Rain Program's NOx provisions. Standard errors in parentheses clustered by state. *, **, and *** indicate P-values of 10, 5, and 1 percent.

Table A2—

Plant characteristics by NOx RACT requirements

	Attainment (1)	NOx RACT (2)	Other O_3 (3)	Differences	
				(1) - (2)	(1) - (3)
Panel (a): 1989 Means					
Log employment	4.782 (0.857)	4.907 (0.742)	4.844 (0.906)	−0.125 (−1.764)	−0.061 (−0.382)
Log generation (MWh)	14.373 (1.410)	14.176 (1.510)	14.414 (1.409)	0.196 (1.483)	−0.041 (−0.163)
Log capacity (MW)	6.323 (0.872)	6.352 (0.848)	6.441 (0.908)	−0.029 (−0.375)	−0.118 (−0.731)
Oldest unit (years)	23.885 (12.220)	30.253 (11.032)	27.843 (9.255)	−6.368*** (−6.158)	−3.958* (−2.320)
Muni	0.258 (0.438)	0.134 (0.342)	0.286 (0.458)	0.123*** (3.597)	−0.028 (−0.344)
Restructured	0.273 (0.446)	0.711 (0.454)	0.257 (0.443)	−0.438*** (−10.802)	0.016 (0.204)
Coal	0.738 (0.440)	0.468 (0.496)	0.629 (0.490)	0.270*** (6.334)	0.110 (1.267)
Gas	0.236 (0.420)	0.333 (0.463)	0.267 (0.441)	−0.097* (−2.422)	−0.031 (−0.392)
PM or SO_2 nonattainment	0.084 (0.278)	0.254 (0.436)	0.200 (0.406)	−0.179*** (−5.320)	−0.124 (−1.843)
Title IV NOx	0.450 (0.498)	0.279 (0.449)	0.343 (0.482)	0.154*** (3.751)	0.100 (1.232)
Plants	322	201	35		
Panel (b): 1987 – 1989 Differences					
Log employment	−0.024 (0.097)	−0.012 (0.124)	−0.045 (0.112)	−0.012 (−1.104)	0.021 (0.970)
Log generation (MWh)	0.075 (0.406)	0.099 (0.453)	0.096 (0.476)	−0.024 (−0.601)	−0.021 (−0.233)
Log capacity (MW)	0.003 (0.051)	0.003 (0.042)	−0.003 (0.017)	−0.000 (−0.016)	0.006 (1.321)
Oldest unit (years)	1.870 (1.932)	2.150 (2.048)	2.000 (0.000)	−0.279 (−1.497)	−0.130 (−1.163)
Plants	301	187	30		

Note: Panel (a) is 1989 sample means and Panel (b) is differences in mean values from 1987 to 1989. Columns (1) and (2) have standard deviations below. difference column has *t*-statistics below. NOx RACT refers to plants in the OTR or Moderate, Serious, or Severe nonattainment areas subject to this regulation. Other O_3 refers to plants in Subpart 1 or Marginal ozone nonattainment areas outside the OTR. Muni is proportion of plants not privately held. Restructured is proportion of plants privately held in areas that initiated electricity market deregulation hearings between 1993 and 1998 and eventually restructured. Coal and Gas are the proportion of plants that reported each as their primary fuel, the remainder were oil. PM or SO_2 is proportion located in a county designated nonattainment for either pollutant. Title IV is proportion affected by the Acid Rain Program's 1996 NOx provisions. *, **, and *** indicate P-values of 10, 5, and 1 percent.

Table A3—

First-stage instrumental variable results

Dependent Variable:	ln(MWh) (1)
State sales	0.724** (0.282)
NOx RACT × 90–92	0.008 (0.041)
NOx RACT × 93–98	−0.016 (0.055)
PM or SO_2 nonattainment × 90–92	0.030 (0.040)
PM or SO_2 nonattainment × 93–98	0.071 (0.054)

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Dependent Variable:	ln(MWh) (1)
South Coast × 90–92	−0.127* (0.073)
South Coast × 93–98	−0.034 (0.165)
Restructured	−0.006 (0.038)
Title IV NOx	−0.034 (0.029)
Muni × 91–92	−0.011 (0.049)
Muni × 93–98	−0.081 (0.059)
Plant F.E.	Yes
Plant-epoch F.E.	Yes
Region × Year × Fuel F.E.	Yes
R^2	0.404
Plant-years	6424
Plant-epochs	715
Plants	594

Note: First-stage regression results for instrumental variable regression in Table 4. State sales is the excluded instrument: natural log of annual state electricity sales in million kWh. Impacts are relative to plants not subject to NOx RACT. 1987–1990 base period impact omitted. NOx RACT refers to plants in the OTR and ozone nonattainment areas (Moderate and above) subject to this regulation. South Coast is a dummy for plants located in California's South Coast Air Quality Monitoring District. PM or SO_2 is a dummy for plants in nonattainment areas for either pollutant. Restructured is a dummy for IOUs in states that restructured electricity markets; it takes a value of unity after initiation of public hearings. Muni is a dummy for plants that are not investor-owned. Title IV NOx is a dummy for plant-years subject to the Acid Rain Program's NOx provisions. Standard errors in parentheses clustered by state. *, **, and *** indicate P-values of 10, 5, and 1 percent.

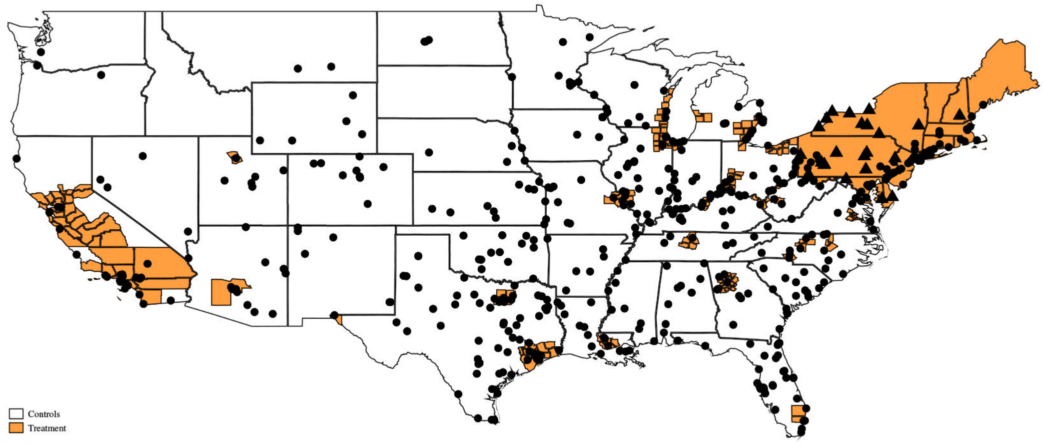


Figure A1. NERC Interconnections and Regions

Source: Foster et al. (2008).

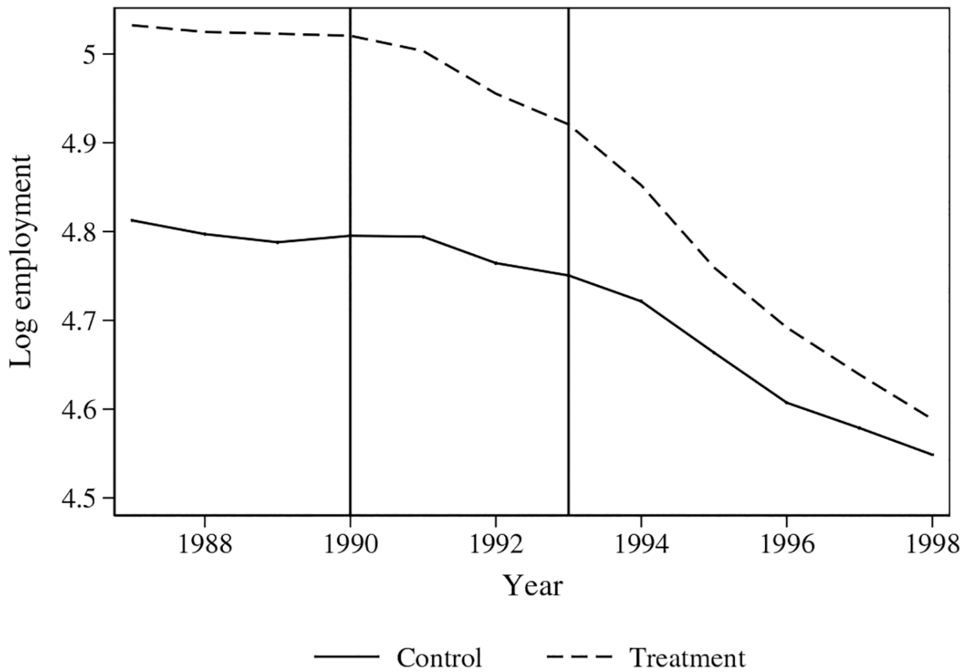
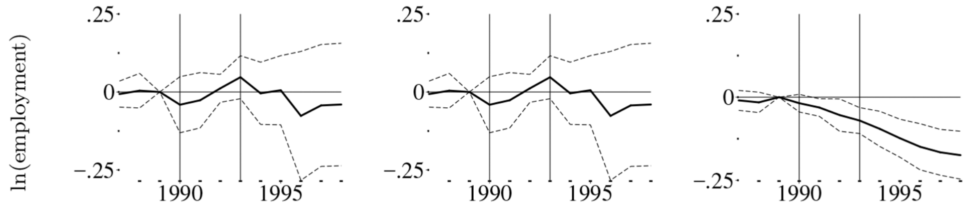


Figure A2. Mean employment trends

Note: Attainment is plants in ozone attainment areas outside the OTR. NOx RACT is plants in the OTR and Moderate and above ozone nonattainment areas. Other O_3 is plants in ozone nonattainment areas not subject to NOx RACT (Subpart 1 and Marginal areas outside the OTR). Series depict plants in a balanced panel.



(a) New O_3 (b) New O_3 and OTR (c) All O_3

Figure A3. Electricity market restructuring in the 1990s.

Note: Shaded states restructured electricity markets by 2001.

Source: Authors, based on data from Fabrizio, Rose and Wolfram (2007).

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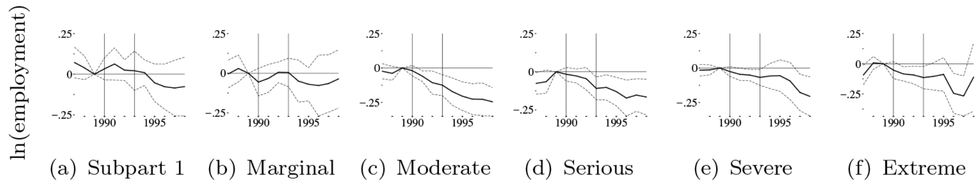

(a) Subpart 1 (b) Marginal (c) Moderate (d) Serious (e) Severe (f) Extreme

Figure 1. Sample plants by NOx RACT applicability

Note: Shaded areas are counties in the OTR and Moderate and above ozone nonattainment areas as of 1993. Triangles depict power plants subject to NOx RACT due to the OTR, not local ozone nonattainment status.

Source: Authors, based on 40 CFR 81, 42 USC §7511c(a).

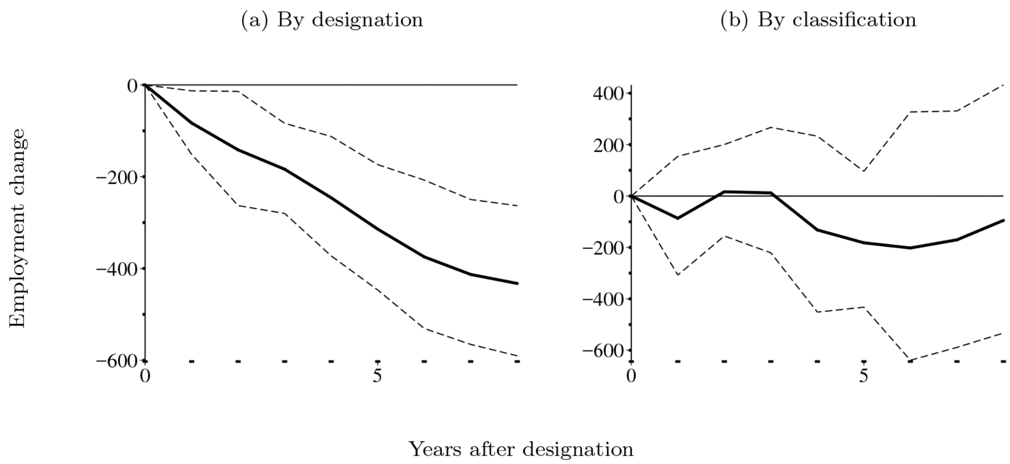

Figure 2. Mean employment trends

Note: Control is plants not subject to NOx RACT (ozone attainment, Subpart 1, and Marginal areas outside the OTR). Treatment is plants subject to NOx RACT (OTR and Moderate and above ozone nonattainment areas). Series depict plants in a balanced panel.

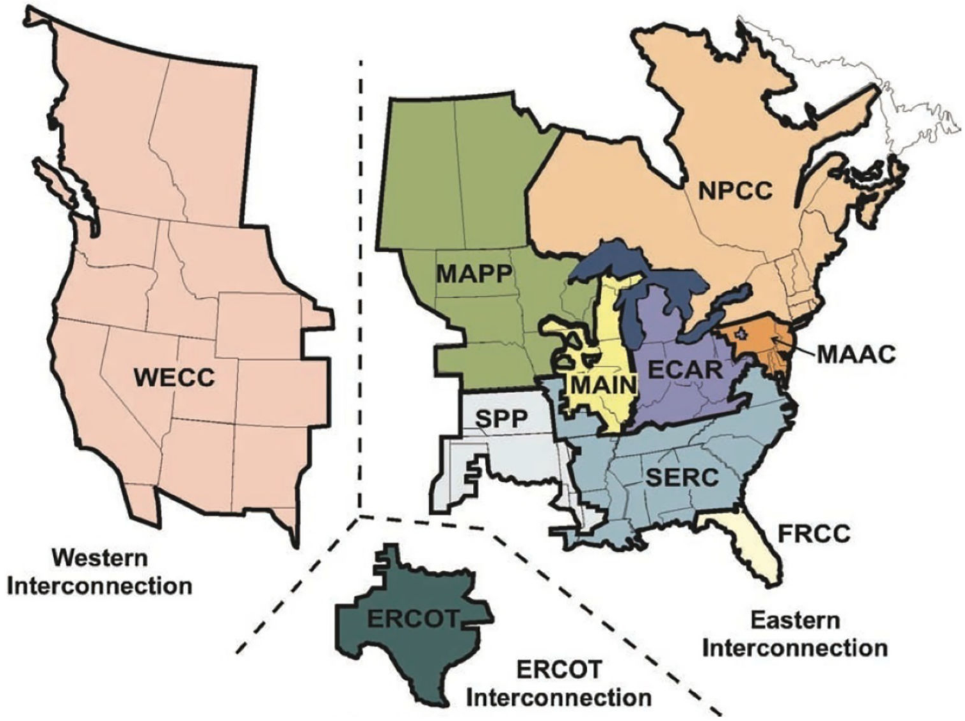

Figure 3. Employment impact of 1993 ozone nonattainment designation over time, by treatment group

Note: Plotted values are coefficients for the interaction between being in ozone nonattainment in 1993 and year. Dashed lines indicate 95 percent confidence intervals. "New O_3" indicates only plants located in counties that switched from attainment to nonattainment between 1989 and 1993 are treated. "New O_3 and OTR" indicates plants in attainment areas in the OTR are also treated. "All O_3" indicates plants always in nonattainment are also treated. In each diagram, control group consists of all untreated plants.

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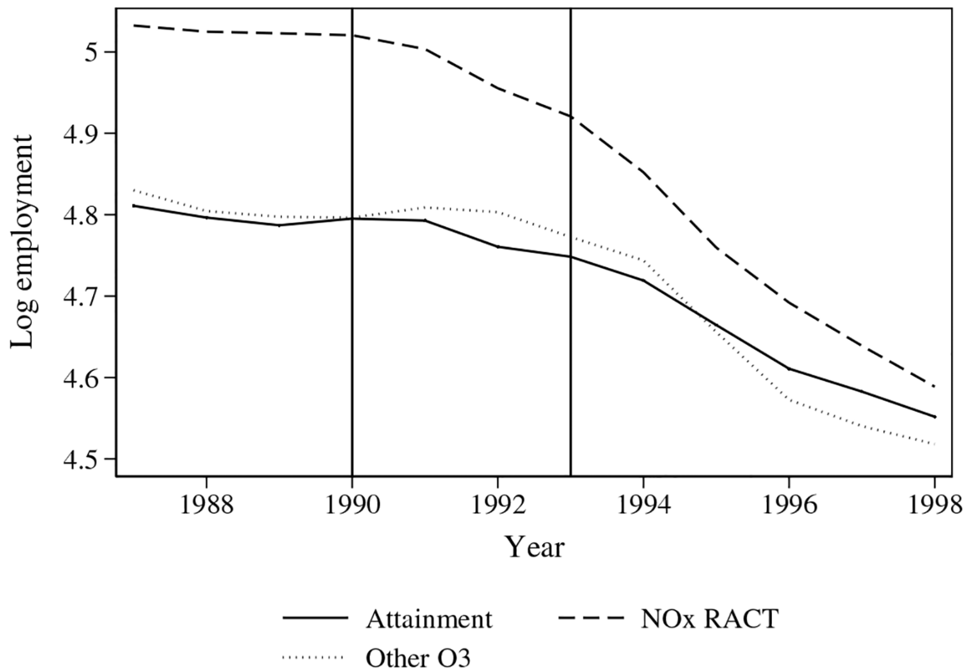

Figure 4. Employment impact of ozone classification over time

Note: Plotted values depict the interaction between being in a given ozone nonattainment classification and year. Dashed lines indicate 95 percent confidence intervals. Moderate includes plants in attainment, Subpart 1, and Marginal areas in the OTR. Extreme plants are also the only plants in California's South Coast Air Quality Management District. Control group is plants always in ozone attainment areas outside the OTR.

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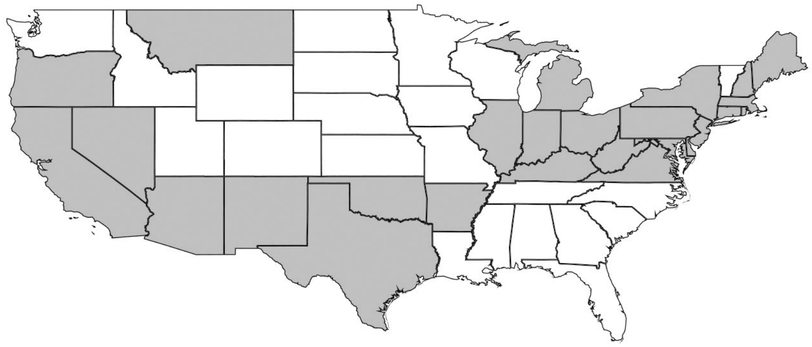

Figure 5. Predicted Employment Impact of 2008 Ozone NAAQS

Note: Plotted values are predicted change in labor demand in counties newly designated as nonattainment with the 2008 Ozone NAAQS relative to plants in attainment counties. Dashed lines indicate 95 percent confidence intervals. Panel (a) does not distinguish among nonattainment classifications. Panel (b) uses parameter estimates appropriate to each plant's county classification.

Table 1—

Pre-treatment plant characteristics for treatment and control groups

	Treatment (1)	Controls (2)	Difference (2) - (1)
Panel (a): 1987–1989 Means			
Log employment	4.907 (0.742)	4.788 (0.860)	−0.119 (−1.714)
Log generation (MWh)	14.176 (1.510)	14.377 (1.408)	0.200 (1.541)
Log capacity (MW)	6.352 (0.848)	6.334 (0.875)	−0.017 (−0.230)
Oldest unit (years)	30.253 (11.032)	24.273 (12.009)	−5.980*** (−5.952)
Muni	0.134 (0.342)	0.261 (0.440)	0.126*** (3.766)
Restructured	0.711 (0.454)	0.272 (0.445)	−0.440*** (−11.055)
Coal	0.468 (0.496)	0.727 (0.445)	0.260*** (6.159)
Gas	0.333 (0.463)	0.239 (0.421)	−0.094* (−2.385)
PM or SO_2 nonattainment	0.254 (0.436)	0.095 (0.294)	−0.158*** (−4.597)
Title IV NOx	0.279 (0.449)	0.440 (0.497)	0.161*** (3.912)
Plants	201	357	
Panel (b): 1987–1989 Differences			
Log employment	−0.012 (0.124)	−0.026 (0.099)	−0.014 (−1.291)
Log generation (MWh)	0.099 (0.453)	0.077 (0.412)	−0.022 (−0.560)
Log capacity (MW)	0.003 (0.042)	0.002 (0.049)	−0.001 (−0.140)
Oldest unit (years)	2.150 (2.048)	1.882 (1.843)	−0.268 (−1.480)
Plants	187	331	

Note: Panel (a) is the mean of within-plant means from 1987 to 1989 and Panel (b) is the mean of within-plant differences from 1987 to 1989. Columns (1) and (2) have standard deviations below. Difference column has *t*-statistics below. Treatment is plants in the OTR or Moderate and above ozone nonattainment areas subject to NOx RACT regulation. Controls is plants in attainment, Marginal or Subpart 1 areas outside the OTR not subject to NOx, RACT. Muni is proportion of plants not privately held. Restructured is proportion of plants privately held in areas that initiated electricity market deregulation hearings between 1993 and 1998 and eventually restructured. Coal and Gas are the proportion of plants that reported each as their primary fuel, the remainder were oil. PM or SO_2 is proportion located in a county designated nonattainment for either pollutant. Title IV NOx is proportion affected by the NOx Acid Rain Program provisions. *, **, and *** indicate P-values of 10, 5, and 1 percent.

Table 2—

NOx RACT impact on employment and generation

Dependent Variable:	ln(employment) (1)	ln(MWh) (2)
NOx RACT × 90–92	−0.030 (0.019)	−0.007 (0.043)
NOx RACT × 93–98	−0.134*** (0.032)	−0.019 (0.052)
PM or SO_2 nonattainment × 90–92	−0.017 (0.019)	0.037 (0.030)
PM or SO_2 nonattainment × 93–98	−0.007 (0.030)	0.053 (0.052)
South Coast × 90–92	−0.015 (0.026)	−0.213*** (0.038)
South Coast × 93–98	0.016 (0.051)	−0.159* (0.088)
Restructured	−0.062 (0.041)	−0.038 (0.046)
Muni × 90–92	0.070*** (0.016)	−0.012 (0.049)
Muni × 93–98	0.073*** (0.022)	−0.086 (0.059)
Title IV NOx	−0.027 (0.019)	−0.021 (0.030)
Plant F.E.	Yes	Yes
Region × Year × Fuel F.E.	Yes	Yes
R^2	0.490	0.295
Plant-years	6424	6424
Plants	594	594

Note: Impacts are relative to plants not subject to NOx RACT. 1987–1989 base period impact omitted. NOx RACT refers to plants in the OTR and ozone nonattainment areas (Moderate and above) subject to this regulation. South Coast is a dummy for plants located in California's South Coast Air Quality Monitoring District. PM or SO_2 is a dummy for plants in nonattainment areas for either pollutant. Restructured is a dummy for IOUs in states that restructured electricity markets; it takes a value of unity after initiation of public hearings. Muni is a dummy for plants that are not investor-owned. Title IV NOx is a dummy for plant-years subject to the Acid Rain Program's NOx provisions. Standard errors in parentheses clustered by state. *, **, and *** indicate P-values of 10, 5, and 1 percent.

Table 3—

Ozone nonattainment impact on employment

Dependent Variable:	ln(employment)			
	(1)	(2)	(3)	(4)
New O_3	−0.008 (0.065)	−0.011 (0.061)		
All O_3 × 90–92			−0.026 (0.019)	
All O_3 × 93–98			−0.121*** (0.028)	
NOx RACT × 90–92				−0.031 (0.020)
NOx RACT × 93–98				−0.143*** (0.032)
Other O_3 × 90–92				−0.013 (0.020)
Other O_3 × 93–98				−0.069 (0.046)
PM or SO_2 nonattainment × 90–92	−0.023 (0.017)	−0.023 (0.017)	−0.017 (0.019)	−0.016 (0.019)
PM or SO_2 nonattainment × 93–98	−0.031 (0.031)	−0.031 (0.032)	−0.002 (0.032)	−0.002 (0.031)
South Coast × 90–92				−0.015 (0.026)
South Coast × 93–98				0.010 (0.052)
Restructured	−0.072* (0.040)	−0.071* (0.040)	−0.063 (0.041)	−0.062 (0.041)
Muni × 90–92	0.072*** (0.017)	0.073*** (0.017)	0.070*** (0.016)	0.070*** (0.016)
Muni × 93–98	0.079*** (0.023)	0.079*** (0.023)	0.078*** (0.022)	0.075*** (0.022)
Title IV NOx	−0.030 (0.020)	−0.030 (0.020)	−0.029 (0.020)	−0.028 (0.020)
Plant F.E.	Yes	Yes	Yes	Yes
Region × Year × Fuel F.E.	Yes	Yes	Yes	Yes
Always nonattainment	Control	Control	Treated	Treated
OTR attainment	Control	Treated	Treated	Treated
R^2	0.480	0.480	0.490	0.492
Plant-years	6424	6424	6424	6424
Plants	594	594	594	594

Note: Model (1) Impacts are relative to plants in counties either always in or always out of ozone attainment. Model (2) impacts are relative to plants in attainment areas outside the OTR or always out of attainment. Model (3) and Model (4) impacts are relative to plants in attainment areas outside the OTR. 1987–1989 base period impact omitted. New O_3 refers to plants in counties that switch from attainment to nonattainment (including OTR attainment counties in Model (2)). NOx RACT refers to plants in the OTR and ozone nonattainment areas (Moderate and above) subject to this regulation. South Coast is a dummy for plants located in California's South Coast Air Quality Monitoring District. PM or SO_2 is a dummy for plants in nonattainment areas for either pollutant. Restructured is a dummy for IOUs in states that restructured electricity markets; it takes a value of unity after initiation of public hearings. Muni is a dummy for plants that are not investor-owned. Title IV NOx is a dummy for plant-years subject to the Acid Rain Program's NOx provisions. Always nonattainment refers to plants in nonattainment counties that do not change status. OTR attainment refers to counties in attainment within the OTR. Standard errors in parentheses clustered by state. *, **, and *** indicate P-values of 10, 5, and 1 percent.

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Table 4—

NOx RACT labor impacts, controlling for generation

	Dependent Variable: ln(employment)	
	(1) OLS	**(2) IV**
NOx RACT × 90–92	−0.039* (0.019)	−0.038 (0.025)
NOx RACT × 93–98	−0.135*** (0.032)	−0.124*** (0.040)
PM or SO_2 nonattainment × 90–92	−0.011 (0.020)	−0.021 (0.027)
PM or SO_2 nonattainment × 93–98	0.000 (0.033)	−0.024 (0.048)
South Coast × 90–92	0.003 (0.021)	0.052 (0.038)
South Coast × 93–98	0.014 (0.056)	0.047 (0.090)
Restructured	−0.052 (0.040)	−0.044 (0.033)
Muni × 90–92	0.073*** (0.018)	0.076*** (0.027)
Muni × 93–98	0.079*** (0.026)	0.108*** (0.036)
Title IV NOx	−0.020 (0.019)	−0.010 (0.023)
ln(MWh)	0.064*** (0.012)	0.434** (0.215)
Plant F.E.	Yes	Yes
Plant-epoch F.E.	Yes	Yes
Region × Year × Fuel F.E.	Yes	Yes
R^2	0.615	0.342
Plant-years	6424	6424
Plant-epochs	715	715
Plants	594	594

Note: IV estimates use log of state electricity sales as an instrument for ln(MWh). Impacts relative to plants not subject to NOx RACT. 1987–1989 base period impact omitted. NOx RACT refers to plants in the OTR and ozone nonattainment areas (Moderate and above) subject to this regulation. South Coast is a dummy for plants located in California's South Coast Air Quality Monitoring District. PM or SO_2 is a dummy for plants in nonattainment areas for either pollutant. Restructured is a dummy for IOUs in states that restructured electricity markets; it takes a value of unity after initiation of public hearings. Muni is a dummy for plants that are not investor-owned. Title IV NOx is a dummy for plant-years subject to the Acid Rain Program's NOx provisions. Standard errors in parentheses clustered by state. *, **, and *** indicate P-values of 10, 5, and 1 percent.

Table 5—

NOx RACT impact on employment: Alternate specifications

Dependent Variable:	ln(employment)						
	(1) Matched Sample[a]	(2) Plant Owner[b]	(3) Electricity Market[c]	(4) Other NAAQS[d]	(5) Input Prices[e]	(6) Entry/Exit[f]	(7) Balanced Panel[g]
NOx RACT × 90–92	−0.032* (0.016)	−0.034 (0.023)	−0.030 (0.019)	−0.014 (0.023)	−0.035** (0.017)	−0.019 (0.060)	−0.023* (0.013)
NOx RACT × 93–98	−0.110*** (0.030)	−0.137*** (0.033)	−0.134*** (0.036)	−0.134*** (0.034)	−0.137*** (0.032)	−0.160* (0.093)	−0.116*** (0.030)
NOx RACT × 90–92 × Variable		0.029 (0.043)		−0.078** (0.038)			
NOx RACT × 93–98 × Variable		0.021 (0.078)	−0.001 (0.058)	0.000 (0.077)			
PM or SO_2 nonattain × 90–92	−0.047* (0.026)	−0.018 (0.019)	−0.017 (0.019)	0.019 (0.020)	−0.016 (0.019)	−0.053 (0.032)	−0.005 (0.012)
PM or SO_2 nonattain × 93–98	−0.038 (0.046)	−0.008 (0.030)	−0.007 (0.030)	−0.006 (0.038)	−0.006 (0.030)	−0.078 (0.067)	−0.015 (0.034)
South Coast × 90–92	−0.008 (0.020)	−0.022 (0.029)	−0.015 (0.027)	0.013 (0.022)	0.002 (0.029)	−0.006 (0.030)	−0.030 (0.025)
South Coast × 93–98	0.056 (0.038)	0.011 (0.054)	0.016 (0.051)	0.015 (0.052)	0.032 (0.051)	−0.013 (0.099)	0.178** (0.073)
Restructured	−0.034 (0.042)	−0.062 (0.041)	−0.062 (0.052)	−0.063 (0.041)	−0.063 (0.042)	−0.047 (0.050)	−0.072* (0.042)
Muni × 90–92	0.090*** (0.031)	0.062*** (0.014)	0.070*** (0.016)	0.072*** (0.016)	0.071*** (0.017)	0.074** (0.032)	0.082*** (0.020)
Muni × 93–98	0.157*** (0.044)	0.068*** (0.020)	0.073*** (0.022)	0.073*** (0.022)	0.076*** (0.024)	0.115** (0.054)	0.091*** (0.030)
Title IV NOx	0.019 (0.033)	−0.027 (0.019)	−0.027 (0.019)	−0.028 (0.019)	−0.029 (0.019)	−0.109** (0.052)	−0.023 (0.020)
ln(wage)					−0.003 (0.022)		
ln(fuel price)					−0.068 (0.047)		
Interaction variable	None	Muni	Restructured	PM or SO_2	None	None	None
Plant F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region × Year × Fuel F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.551	0.490	0.490	0.491	0.493	0.177	0.536
Plant-years	3335	6424	6424	6424	6322	6495	4860
Plants	299	594	594	594	588	594	405

Note: Impacts are relative to plants not subject to NOx RACT. 1987–1989 base period impact omitted. NOx RACT refers to plants in the OTR and ozone nonattainment areas (Moderate and above) subject to this regulation. South Coast is a dummy for plants located in California's South Coast Air Quality Monitoring District. PM or SO_2 is a dummy for plants in nonattainment areas for either pollutant. Restructured is a dummy for IOUs in states that restructured electricity markets; it takes a value of unity after initiation of public hearings. Muni is a dummy for plants that are not investor-owned. Title IV NOx is a dummy for plant-years subject to the Acid Rain Program's NOx provisions. "Variable" signifies that the term is interacted with the "Interaction variable" listed at the bottom of the table. Standard errors in parentheses clustered by state.

[a] Nearest neighbor with replacement.

[b] Dummy for non-privately owned plants.

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[c] Dummy for investor-owned plants in restructuring states after initiation of public hearings.

[d] Dummy for plants in counties out of attainment for either PM_{10} or SO_2 NAAQS.

[e] Controls for input prices. Fuel price data are unavailable for 102 plant-years.

[f] One employee imputed to missing years for entering and exiting plants and plants reporting non-positive net generation in eGRID.

[g] Includes only plants with no missing data.

*, **, and *** indicate P-values of 10, 5, and 1 percent.

Table 6—

Potential plant entry and exit by year and 1993 NOx RACT status

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Potential entries										
NOx RACT	0	0	0	1	0	0	1	0	0	0
Controls	2	0	0	2	0	1	0	0	2	2
Potential exits										
NOx RACT	0	0	0	0	1	0	0	0	0	0
Controls	0	0	0	0	0	0	0	0	0	0

Note: Potential entries are number of plants that first appear in the Fabrizio, Rose and Wolfram (2007) data in a given year and whose plant age is either zero or one. Potential exits are number of plants that are first missing from this data set in a given year, are missing from the data set for all subsequent years, and have nonpositive generation reported in eGRID from 1996–1999. NOx RACT is the OTR and Moderate and above ozone nonattainment areas. Controls refers to plants in ozone attainment, Subpart 1 and Marginal areas.