The 1990 Clean Air Act Ozone Rules and Labor Demand for Electricity Generation: Do Stringency, Implementation, and Timing Matter?

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Abstract

Policy makers are keenly interested in understanding short-term employment impacts of environmental regulation. Current empirical research in this area relies on restrictive assumptions regarding the institutional structure of regulation and definition of the regulated sector. The 1990 Clean Air Act Amendments introduced a new classification regime for ozone non-attainment areas. The resulting geographical heterogeneity in timing, stringency, and implementation of ozone National Ambient Air Quality Standards allows us to relax these assumptions and develop a more nuanced understanding of how air rules affected relative employment growth in the electricity generation sector in the 1990s.

Key words: environment, regulation, employment impacts, employment growth, electricity generation

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The question of how environmental rules impact short to medium term employment growth in regulated entities is of paramount importance to policy makers, but has received relatively little attention from economists. Ozone National Ambient Air Quality Standards (NAAQS) are of particular salience due to their high projected costs. Theoretically, however, compliance costs have an ambiguous impact on sector-level employment (Berman and Bui, 2001; Morgenstern, Pizer, and Shih, 2002; Gray et al., 2011; Gray and Shadbegian, 2013). In this paper, we take advantage of geographic heterogeneity in the implementation, stringency, and timing of ozone regulations to assess how tightening ozone regulations affected plant-level employment growth in the highly regulated electricity generation sector in the 1990s.

Ground-level ozone NAAQS have been set under the Clean Air Act since 1970.[1] Although states have the primary role in implementation and enforcement, the 1990 Clean Air Act Amendments (CAAAs) significantly strengthened the federal role. We take advantage of three aspects of these changes to identify the impact of ozone standards on electricity generating units (EGUs).

Prior to 1990, designation was dichotomous; an area was either in or out of attainment with respect to NAAQS. The 1990 CAAAs introduced classifications of ozone non-attainment areas ranging from marginal to extreme, reflecting air quality at the worst monitoring station. Stringency of mandatory controls increased cumulatively as the classification got worse. Unlike previous research, (e.g., Greenstone, 2002; Walker, 2011) we take advantage of this variation to estimate the impact of different levels of regulatory stringency.

Second, the non-attainment designation date published in the Federal Register (FR) and codified in the Code of Federal Regulations (CFR) is not necessarily the date that regulations became effective.[2] Under the Clean Air Act, the federal government is responsible for setting ambient air quality standards, but states are responsible for implementing regulations to achieve them. These regulations become part of a State Implementation Plan (SIP), which becomes federally enforceable when approved by the EPA. Thus, rather than directly regulating emission sources, the designation date starts the clock on a multi-year process in which states submit SIPs for EPA approval.[3] States generally promulgate implementing regulations as part of their SIP submission. SIP submission dates vary by state, and do not necessarily coincide with statutory deadlines. If states do not submit SIPs in a timely manner, or if the SIPs fail to adhere to the requirements of the Act, the EPA can impose regulation with a Federal Implementation Plan.

We take advantage of the fact that the 1990 CAAAs introduced new requirements based on ozone classification to understand the impact of specifying different "start" dates for plant-level regulations. We evaluate three alternative regulation start dates: (i) 1991, the year following the 1990 CAAAs, (ii) 1993, the year SIPs were due, and (iii) the years states actually submitted their

[1] While ozone is beneficial in the stratosphere, at ground level it causes adverse health and environmental impacts (National Research Council, 2008).

[2] United States legislation typically grants broad latitude to executive branch agencies to implement details of the law. The environmental title of the CFR, published each July, is the codification of these regulations. New or amended regulations are published daily in the FR. FR notices cross-reference the affected part of the CFR. Throughout this document, we use the standard abbreviated citation for the CFR and FR. The number preceding CFR indicates the Title, and the number after CFR indicates the Part. The number preceding FR indicates the Volume, and the number after FR indicates the page.

[3] SIPs contain several elements including New Source Review rules, definitions and application of control technologies for stationary sources, control strategies for mobile sources, setting up air quality networks, etc. There are different statutory deadlines for submitting these various elements. Thus, a SIP is generally not a single document. For more details on SIP requirements, see 40 CFR 51.

SIPs.[4]

Third, we utilize heterogeneity in geographic implementation of the ozone regulations in our identification strategy. The 1990 CAAAs introduced two notable changes in boundary definitions of ozone non-attainment areas. First, boundaries of Serious, Severe, or Extreme non-attainment areas located within a Metropolitan Statistical Area (MSA) expanded to include the entire MSA. This redefinition shifted some counties that previously would not have been stringently regulated under the new classification system, based on their air quality monitoring data, into stricter classifications. Second, the statute created the Ozone Transport Region (OTR) in northeast and mid-Atlantic states. The OTR regulated all counties within those states as at least Moderate ozone non-attainment areas, regardless of local air quality or distance to an MSA. So, for example, counties in rural Pennsylvania that were in attainment for ozone, were newly regulated as moderate non-attainment under the OTR.

The remainder of the paper is organized as follows. Section 1 reviews how the previous literature has evaluated the economic impact of the Clean Air Act. Section 2 describes the institutional framework of ozone NAAQS regulation in greater detail. In Section 3 we describe our theoretical framework. Section 4 discusses our data. In Section 5 we discuss our empirical methodology and our preliminary results. In Section 6 we outline the next steps we will take to refine our results, and Section 7 offers preliminary conclusions.

1 Literature

Our focus on regulatory institutional details is similar in spirit to Berman and Bui (2001). That study estimated the employment impact of strict local air quality regulations in California's South Coast Air Quality Monitoring District. The authors compiled a detailed compendium of plant-specific air regulations for the manufacturing sector, along with adoption and compliance dates. After controlling for national industrial sector trends, they found that local rules significantly impacted investments in pollution abatement, but not employment. Importantly, the study found evidence that the relevant date of impact is the date by which firms must comply with the rule, rather than the date that a rule is announced. Although we do not amass plant-specific local regulatory details, the structure of the CAAAs allow us to examine the impact of requirements that vary in stringency across locations. Similar to Berman and Bui (2001), we are also able to distinguish between the rules' announcement and compliance dates.

Over the past twenty years, it has become common for researchers to use geographical heterogeneity in regulatory stringency mandated by the CAAAs as a quasi-experiment to test hypotheses regarding effects of environmental regulation. In essence, plants in attainment areas serve as a control group with which to compare outcomes in treated plants in the more heavily regulated non-attainment areas. This approach has been used to study pollution levels (Henderson, 1996; Kahn, 1997; Greenstone, 2003, 2004; Auffhammer, Bento, and Lowe, 2009), housing prices (Chay and Greenstone, 2005), productivity (Greenstone, List, and Syverson, 2012), county tax revenue (Carr, 2011), and industrial sector diversity (Carr and Yan, 2012).

Our research is most closely related to work on plant 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;

[4] In this draft we only evaluate the first two dates, but we have data to evaluate the third in the next draft.

Condliffe and Morgan, 2009; Morgan and Condliffe, 2009) and labor demand (Greenstone, 2002; Walker, 2011). Henderson (1996) sparked a large literature estimating the impact of ozone non-attainment on changes in the number of plants. Studies consistently find that, relative to attainment areas, non-attainment designations adversely affect plant economic decisions, finding reduced plant births (Becker and Henderson, 2000; List, McHone, and Millimet, 2003; Condliffe and Morgan, 2009; Morgan and Condliffe, 2009), increased relocations (List et al., 2003), reduced modifications (List, Millimet, and McHone, 2004), and increased pollution abatement costs (Becker, 2005). Regarding labor impacts, Greenstone (2002) used changes in attainment status of NAAQS under the 1970 and 1977 CAAAs to identify employment effects of increased regulation on polluting plants in newly designated non-attainment counties. Walker (2011) extended this work to analyze medium-term effects of the 1990 CAAAs.

In contrast to Berman and Bui (2001) these studies estimate a regulation's impact based on non-attainment designation date, not the date on which rules become effective. As we discuss in Section 2, this distinction is particularly important for ozone New Source Review (NSR) rules after 1990.[5] These studies use county or plant level fixed effects to control for unobserved time invariant characteristics that could affect the outcome variables. Consequently, identification is obtained from regulated plants that switch designation status.

A key decision in this framework is how to define "regulated." The standard approach is to define regulated as the intersection of being a polluting plant and being in a non-attainment county. Early work, including Becker and Henderson (2000) and Greenstone (2002), defines polluting plants based on the relative emission levels of their two-digit Standard Industrial Classification (SIC) code, as recorded in the EPA's Sector Notebook Project. Becker and Henderson (2000) classify plants as heavily polluting if they are in a sector responsible for 25,000 tons per year of VOC, and NOx and VOCs constitute over 60 percent of total emissions. Greenstone (2002) labels a sector as polluting if it is responsible for at least 7 percent of national industrial emissions for a given pollutant. A potential problem with both these approaches is that they may mislabel small sectors with high emissions per plant as not polluting, and large sectors with low emissions per plant as polluting. This mislabeling can be problematic since the CAAAs' NAAQS regulations apply to large emitters on a per plant basis, not a per sector basis.

Other studies, for example Becker (2005) and Morgan and Condliffe (2009), use the EPA's Aerometric Information Retrieval System (AIRS) database to define polluting plants. Becker (2005) defines a four-digit SIC code as being a "high emitter" for a given pollutant if a certain number of establishments in the sector have emissions that exceed the EPA's reporting threshold (typically 100 tons per year) for that pollutant. He chose this level so that the number of high emitters would be no more than 50 percent of the sample. This approach also has the possibility of mislabeling low emission plants as high emitters or high emission plants as low emitters.

Walker (2011) defines polluting plants using a different EPA database, the Air Facility Subsystem (AFS).[6] AFS has the advantage of containing plant-level information on air permits by pollutant. Under the assumption that the EPA issues permits to a plant if and only if it pollutes, this approach would appear to be ideal. Unfortunately, using the AFS in this way is not immune from mis-classifying plants since several states have alternative Federally Enforceable State Operating

[5]The distinction is also relevant for PM_{10} and CO NSR rules.

[6]See `http://www.epa.gov/enviro/facts/afs/index.html`.

Permitting programs that may not necessarily appear in AFS.[7] The AFS also has the disadvantage that it is only a current snapshot of permits; it is not a historical panel of regulated facilities. Thus, if plant emissions are not constant over time, the AFS can mischaracterize polluters during the period of analysis. A large permitted facility in the current AFS database may have been a minor source in 1993, for example, or a large emitter in the 1990s may have since scaled back operations.

The next step is to choose an appropriate control group. Greenstone (2002) combined SIC-level emission data with plant-level production data from the 1967, 1972, 1977, 1982, and 1987 Census of Manufacturers. These data allowed him to control for unobserved time invariant confounding factors with plant-level fixed effects. Consequently, these estimates are based on the difference in the growth rate of employment for a polluting plant during a period in which it is in an attainment county compared to the growth rate for the same plant during a period in which it is in non-attainment.

Walker (2011) took advantage of plant-level permit information from the AFS database, combined with annual plant-level data from the U.S. Census Bureaus Longitudinal Business Database. These data increased the potential accuracy of Walker's estimates vis-a-vis Greenstone (2002), by allowing for a triple-difference estimator. This innovative framework compares the difference in employment between polluting and non-polluting industrial plants in non-attainment counties with the difference between polluting and non-polluting plants in attainment counties, before and shortly after the 1990 CAAAs, while using plant-level fixed effects to control for unobservable confounding factors.

Here, we focus specifically on the electricity generation sector. All plants in our sample are major sources of NOx[8], as defined by the CAA, and so unquestionably fall in the "polluting" category. In this regard, all plants in our sample in non-attainment areas are regulated, but most importantly, to varying degrees of stringency. We assign plants into seven categories of regulatory stringency based on contemporaneous ozone classifications. Rather than relying on a grouping of non-regulated plants for a third difference, we improve upon our control group by employing a matching technique to further refine the composition of plants in attainment counties in our sample, to more closely approximate those plants in non-attainment areas.

2 Ozone regulation under the Clean Air Act

The 1970 CAAAs introduced NAAQS for a set of "criteria" air pollutants, among them ozone.[9] Although the EPA was responsible for setting the NAAQS, the statute left implementation and area designation to the states. After a lack of progress in achieving these standards, Congress enacted the 1977 CAAAs. These amendments gave the EPA temporary power to designate areas as being out of attainment, and also gave the EPA the power to sanction states that do not comply with their responsibilities by taking over implementation via Federal Implementation Plans, banning new construction, and withholding grant money and highway funding, among other things.

[7] See `http://www.epa.gov/reg5oair/permits/oper.html`.

[8] Ground level ozone is created by a photochemical reaction to which both VOCs and NOx are precursors.

[9] The other criteria pollutants are particulate matter, carbon monoxide, lead, sulfur dioxide, and nitrogen dioxide. Particulate matter was originally defined as Total Suspended Particulates (TSP) comprising particles smaller than 40 microns. In 1987, the EPA revised the standard to cover only particles smaller than 10 microns, PM_{10} (52 FR 24634). In 1997, the EPA preserved the PM_{10} standard, and added a stricter standard for particles smaller than 2.5 microns, $PM_{2.5}$ (62 FR 38652).

The 1977 CAAAs treated criteria pollutants equally. States were responsible for monitoring ambient pollution in their air quality regions (which often, but not necessarily, coincided with county boundaries), and for submitting changes in attainment status to the EPA. New and modified major stationary sources (those emitting more than 100 tons per year of any criteria pollutant) in attainment areas have been governed under Prevention of Significant Deterioration (PSD) requirements. Under PSD, these sources must demonstrate that they will not significantly impair ambient air quality and must install best available control technology (BACT). Plants can use cost considerations when selecting BACT.

In non-attainment areas, new or modified major stationary sources (those emitting more than 100 tons per year of the criteria pollutant for which the area is in non-attainment) were subject to stricter New Source Review (NSR) requirements. Among other things, NSR imposed two requirements on plants. First, these sources were required to install Lowest Achievable Emission Rate controls regardless of cost. Second, they were required to offset emission increases with reductions elsewhere in the area at a ratio of 1:1. Existing major sources faced the less stringent requirement of retrofitting with Reasonably Available Control Technology (RACT), for which cost could be considered in the definition of "reasonably".

Under the 1990 CAAAs these requirements were preserved under Subpart 1 of Title I of the Act. In addition to Subpart 1, ozone was governed under stricter requirements set forth in Subpart 2.[10] Subpart 2 divided non-attainment into several classifications. The classifications imposed increasingly strict requirements based upon the degree to which an area's ambient pollution concentration exceeded the standard. Subpart 2 also extended ozone regulations to cover sources of oxides of nitrogen (NOx); previously only sources of volatile organic compounds (VOCs) were covered.[11]

Under Supbart 2, ozone non-attainment areas have six main classifications: Transitional, Marginal, Moderate, Serious, Severe, and Extreme.[12] Transitional areas were regulated under the requirements of Subpart 1 only. With respect to stationary source regulation, the other classifications differ in four main aspects: the threshold for defining a "major" source gradually falls from 100 tons per year for Marginal areas to 10 tons per year for Extreme areas; NSR offset requirements are gradually increased from ratios of 1.1:1, to 1.5:1; RACT requirements become more strict for Moderate and above areas; and the threshold for what qualifies as a significant modification for NSR purposes is lowered from 40 to 25 additional tons per year in Serious and Severe areas and eliminated for Extreme areas.[13]

Statutory requirements accumulate with each increase in classification. Marginal areas, for example, must comply with all requirements of areas regulated under Subpart 1, and Extreme areas must satisfy the requirements of all other classifications. In addition to plant-level requirements areas may be required to undertake a range of other actions such as vehicle inspection and mainte-

[10]The Act did not change the standard itself, which the EPA set in 1979. The 1979 standard was defined as one day or less per calendar year expected to have a maximum hourly average concentration exceeding 0.12 ppm (44 FR 8202).

[11]VOCs and NOx are ozone precursors.

[12]In addition, a single Submarginal area was essentially regulated as Transitional, and there are two grades of Serious classification, 15 and 17, referring to the number of years allowed for the area to come into attainment.

[13]Other major stationary source requirements include annual emissions statements (Moderate and above), an emissions fee if the area fails to attain by deadline (Serious and Extreme), and clean fuel, such as natural gas, or advanced control technologies for all boilers emitting more than 25 tons per year of NOx (Extreme).

Figure 1: 1990 Clean Air Act Requirements for Ozone Non-attainment Areas

Classification	Cumulative Requirements	Major Source Threshold* (tons/year)	NSR Offset* (ratio)	Attainment Deadline (years)
Extreme	NSR triggered by any modification*; Traffic Controls; Clean Fuels for Boilers*	10	1.5:1	20
Severe	VMT Growth Offset; Low VOC Reformulated Gasoline; Penalty Fee Program for Major Sources*	25	1.3:1	15 or 17
Serious	Vehicle Miles Travelled (VMT) Demonstration; Milestone Contingency Measures for RFP; Modeled Attainment Demonstration; Enhanced Vehicle I/M; Clean Fuels Program; NSR triggered by smaller modification*; Average 3% RFP per year after year 6; Enhanced Monitoring Plan	50	1.2:1	9
Moderate	Vehicle Inspection/Maintenance (I/M); 15% RFP Over 6 Years; Stage II Gasoline Vapor Recovery; Enhanced RACT*; Attainment Demonstration; Contingency Measures	100	1.15:1	6
Marginal	NOx Requirements*; Periodic EI Updates; Major Source Emission Statements*	100	1.1:1	3
Transitional (VOC only)	Reasonable Further Progress (RFP); Reasonably Available Control Measures; Reasonably Available Control Technology (RACT) for some existing major sources*; New Source Review (NSR) Program: Lowest Achievable Emission Rate and Offsets*; Transportation Conformity; Emission Inventory (EI); Emission Growth Projection	100	1:1	5

Notes: Requirements for each classification include those of all lower classifications. This figure is a general summary, see Clean Air Act Title I, Part D, Subparts 1 and 2 for details, including possible exemptions and waivers. *Requirement applies to individual major stationary sources.
Source: Authors, adapted from EPA, based on information from Wooley and Morss (2012).

nance programs, submitting an emissions inventory, demonstrating reasonable further progress in area-wide emissions reductions, etc. Figure 1 provides details regarding statutory requirements for each classification.

Recognizing that emissions from mobile sources are a significant source of ozone precursors, and that emissions can travel great distances, the 1990 CAAAs extended the geographic areas subject to non-attainment status in two ways. First, for Serious and greater ozone non-attainment areas located within a metropolitan statistical area, non-attainment area boundaries were expanded to include the entire metropolitan statistical area (42 USC §7407(d)(4)).[14] Second, Subpart 2 also created a permanent Ozone Transport Region (OTR) comprising the entire states of 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 that are in the Washington, DC Consolidated Metropolitan Statistical Area (42 USC §7511c(a)). All major stationary sources in the OTR are regulated at least as if they were in Moderate non-attainment, regardless of local air quality, except that sources in the OTR are considered major if they emit more than 50 tons per year, rather than 100. During the late 1990s, member states of the OTR tightened electricity generation unit (EGU) NOx RACT rules and set a cap on total OTR NOx emissions from EGUs.

In addition to these ozone-specific changes, the 1990 CAAAs changed the general NAAQS designation process. Previously, states were responsible for submitting requests for changes in designation status to the EPA at their own initiative. By operation of law, the Act itself desig-

[14]The Act made a similar boundary adjustment for CO non-attainment areas.

nated new non-attainment areas for ozone, CO, and PM_{10}. In addition, Congress granted the EPA more power in the designation process. States are now required to propose designations within one year of promulgation of a new or revised standard, and the EPA has broad authority at any time to request that states propose changes in designation status (based on air quality data, for example) within 120 days. Based on these proposals, the EPA Administrator makes the final decision regarding designation status.

3 Theoretical Framework

Theoretical models in Berman and Bui (2001) and Morgenstern et al. (2002) show that the sign of net plant-level employment impacts of environmental regulation for affected industries is ambiguous. There are competing effects: pollution-reduction compliance activities themselves are likely to increase labor demand to install and operate equipment, but compliance costs raise production cost. To the degree that plants pass along these cost increases to consumers, output demand may fall, negatively affecting labor demand.

Plant-specific requirements of the 1990 CAAAs for ozone non-attainment areas can be broken down into two broad categories: those applying to new or modified sources, and those applying to existing sources. Both types of requirements involve a two-stage decision-making process for affected facilities.[15] The first stage is to calculate compliance costs (installing controls, acquiring offsets, using a clean fuel, etc.). The second stage is to evaluate whether, based on the first stage analysis, it is worth undertaking an action that will trigger compliance costs. For potential new or modified sources, this trigger is undertaking new construction. For existing source requirements, the trigger is simply to keep operating versus closing the plant.

The sign of employment growth changes from ozone requirements is unambiguously negative for existing plants that decide to close or for potential new plants that decide not to initiate construction. For any remaining local competitors, however, the impact may be positive. Relative to the counterfactual, remaining competitors may find an increase in demand for their output. By expanding production to meet this displaced demand, remaining plants may increase plant-level employment.

For existing plants that elect not to undertake a modification, the employment impact is not clear. If the modification would have expanded output it may have increased demand for labor. If, however, the modification would have changed the production technology such that less labor would be used per unit of output, then the modification may have reduced the net demand for labor. Moreover, similar to the case in which plants decide to exit or not enter, local competitors may increase employment to meet displaced demand if the foregone modification would have increased output.

Berman and Bui (2001) and Morgenstern, Pizer, and Shih (2002) focus on net employment impacts for plants that elect to trigger compliance requirements, and find that they are similarly ambiguous. Compliance activity itself is likely to increase labor demand because labor is required to install and operate the equipment, all else equal. To the extent that compliance activity raises costs and plants pass this cost to consumers, however, demand for the plant's output may fall. Any corresponding drop in production should reduce labor demand for an affected facility.

[15] We assume that enforcement mechanisms are adequate to prevent criminal behavior.

To further complicate matters, we expect that electric utilities would have responded strategically to the new ozone regulations by adapting production decisions temporally and geographically. The regulations may have induced changes in the timing of production decisions. For example, an EGU that was considering expanding capacity by installing another boiler may have accelerated construction to avoid triggering upcoming NSR rules which would come into effect only after their state updated its code of regulations. Another example of a strategic response could be geographic shifts in electricity generation. For a utility with power plants in different locations it may be efficient to shift production from those areas with relatively strict to areas with relatively lax requirements, particularly within a North American Electric Reliability Corporation (NERC) region.[16] Failure to account for such shifts may exaggerate estimated employment impacts.

In sum, microeconomic theory provides no clear prediction regarding net effects of ozone nonattainment status on EGU plant-level employment growth. The subsequent sections describe our strategy for taking this question to the data.

4 Data

To estimate potential impacts on plant-level employment growth from the 1990 CAAAs, controlling for key plant-level observables and macroeconomic characteristics, we compile a panel dataset of electric utilities and ozone classifications for their locations. We first construct an unbalanced panel data set of 497 EGUs from 1988-1999, with 5,878 plant-year observations.[17] Our main facility-level data are 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). This data set provides annual information on the total number of employees, plant nameplate capacity (MW), plant utilization (net MWh generation), plant age (installation year of oldest boiler), heat input (mmBTUs), and primary fuel type.

County-level 1-hour ozone classifications come from EPA's Green Book.[18] File `nayro.xls` contains a snapshot of ozone classifications for the mid 1990s, and `phistory.xls` contains time-varying ozone nonattainment designations. We note that a few areas in the `nayro.xls` spreadsheet are coded as Other, and we checked their information against the relevant FR notice to code them into their appropriate classifications. We use information from `phistory.xls` to create an indicator variable for nonattainment status prior to the 1990 CAAAs.[19]

It is important to note that the Green Book does not include information on the OTR. We use information in 42 USC §7511c(a) to adjust our coding of ozone classification to account for the regulatory status implied by the OTR (i.e., attainment and marginal non-attainment areas are regulated as if they were moderate non-attainment areas). In addition, we code separately those

[16]Electricity generation and transmission is coordinated at the regional level. For a map of NERC regions, see `http://www.nerc.com/page.php?cid=1%7C9%7C119`.

[17]We are currently in the process of updating our data set, soon we will be able to add more years before 1988 and after 1999. We also hope to be able to add back in some plants that we dropped from our current data set. There are 726 fossil fuel fired EGUs operating by 1990 that reported at least some output data on EIA767. We removed 229 plants that did not report or had implausible or inconsistent values for key variables (e.g., employment, output).

[18]See http://www.epa.gov/oaqps001/greenbk/index.html

[19]We are currently compiling ozone classification dates from 40 CFR 81, which will enable us to replace the information from `nayro.xls` with time-varying ozone classifications.

areas that switched status solely due to the OTR.

Tables 1 and 2 present summary statistics for EGUs for one year before and after the 1990 CAAAs. We report means and standard deviations for plants in our sample, for selected variables of interest, in both 1989 and 1991. The distribution of plants within the ozone non-attainment classifications and their characteristics, is listed in Table 2.

The left side of Table 1 presents data for 1989. The most notable differences are that attainment area plants are younger and much more reliant upon coal. In addition, in spite of markedly lower capacity, attainment area plants have slightly higher utilization rates. Plant-level employment rates, however, are similar between the two categories.

The right side of Table 1 summarizes 1991 data. While characteristics of attainment areas hold steady in the two periods, attainment area plants show a decrease in both capacity, utilization rates, and employment. Because our treatment group differs on these observable characteristics prior to the 1990 CAAAs, we use this information as covariates in our estimation, as detailed in the next section.

Table 2 shows the same characteristics for non-attainment plants in 1991, broken down by ozone classification and OTR status. As expected, because coal-fired power plants are more labor-intensive than natural gas, employment appears to be positively correlated with coal usage (in terms of percent of BTUs) across the classifications. Plants in Extreme areas stand out from the rest. They are among the oldest plants, and use no coal. They have the second lowest capacity (after Serious), and have the lowest utilization and employment. Also noteworthy are the OTR plants. They are as old as the Extreme plants, but in contrast have the highest coal use, 85 percent. They have the second highest capacity, the highest utilization, and above average employment. If ozone regulations have a stronger impact on older coal-fired plants, then we would expect the OTR group to be particularly vulnerable. In addition, plants in the OTR group, as defined here, were previously not regulated for ozone at all (they were in attainment prior to the 1990 CAAAs) and so may have been less prepared for the stringency of the new ozone regulations.

5 Empirical Approach

5.1 Modeling the 1990 CAAAs

The timing of regulations is an important component in any evaluation of regulatory effects. We model three alternative specifications regarding effective regulatory start date: (i) 1991, the first year after passage of the statute; (ii) 1993, the first full year after NSR SIP revision deadline; and (iii) the actual NSR SIP submission year, which varies by state.[20] The first specification, used in Walker (2011), implicitly assumes that plants react to the impending rules at the time of publication, before states begin enforcement. The second specification assumes that the relevant start date is when states *should* have implementation rules on the books, 1993. The third specification uses the date when states actually have implementation rules.[21]

For the 1991 and 1993 specifications, we utilize a Difference in Differences (DiD) approach, enhanced by matching. We construct a time invariant indicator variable for each non-attainment classification taking a value of one if a plant is at any time in an area with that classification. We

[20] We code a regulatory action taking place after November 1 as belonging to the subsequent calendar year.

[21] In this draft of the paper we only evaluate the first two dates, but we have data necessary to evaluate the remaining dates for the next draft.

also construct indicator variables that take a value of one for all years after the treatment year (1991 or 1993). The interaction of these two indicators identifies those observations that are in non-attainment areas after the regulation comes into effect. The coefficient of the interaction term can be interpreted as the average regulatory effect of a given classification, relative to attainment areas, on plant-level employment growth over the corresponding post treatment period.

Detailed information on the implementation and stringency of ozone regulations provides more opportunities for identification of effects, relative to the standard approach in the literature. Doing so, however, requires detailed knowledge of the regulations, which is not always easily available to researchers. The existence of the OTR presents a challenge for labeling non-attainment areas. The OTR is not a designation per se, and as such does not appear in 40 CFR 81. Nor does it appear in commonly used compilations of the CFR designations such as EPA's Green Book. Thus studies such as Walker (2011) that rely on these data sources would incorrectly label attainment OTR counties as being unregulated. Since these counties are more heavily regulated than attainment areas, we examine the sensitivity of our results to alternative treatment of the OTR.[22]

Our second specification considers the scenario in which state regulations become effective in 1993, the first full year after the NSR SIP revision deadline, while our third specification considers the scenario in which state regulations do not become effective until states submit their NSR SIPs.[23] We chose the NSR SIP submittal date since the NSR rules are arguably the most costly regulatory difference between attainment and non-attainment areas. In principle, NSR rules should come into effect immediately upon promulgation, since there are no delayed compliance dates as is common for RACT retrofits. SIP submittal dates introduce further heterogeneity into the analysis, ranging from 1990 into the 2000s, with even a few very late outliers. [Under construction, results forthcoming.]

Greenstone (2002) and List, McHone, and Millimet (2003) raise the question of the validity of using changes in county ozone non-attainment status to identify the impact of the CAAAs. Suppose that a county has an unobserved characteristic that changes over time. For example, there may be a growing demand for a locally made good whose production emits VOCs. This growing demand leads to expanded production as well as emissions. The increase in emissions causes a change in attainment status. Suppose demand continues to grow after the change in status. If this change in demand is unobserved, the regression will falsely attribute the increased economic activity to the change in attainment status.

Two commonly used controls, county and year fixed effects do not solve this problem. County fixed effects only control for time invariant unobservables, and thus do not capture effects of demand that grows over time. Year fixed effects only control for time varying unobservables that are

[22]In a quirk of the law, attainment areas in the OTR are actually more regulated than Moderate non-attainment areas in the OTR since they also need to comply with analytical PSD requirements.

[23]The 1990 CAAAs explicitly require states to submit NSR SIP revisions reflecting changes in treatment of ozone non-attainment areas by November 15, 1992. In a pair of non-binding guidance memos, the EPA indicated that it would interpret the Act to mean that new or modified major stationary sources could be permitted under the Subpart 1 until a state submitted an NSR SIP revision or the 1992 deadline, whichever came first (see John S. Seitz, "New Source Review (NSR) Program Transitional Guidance," March 11, 1991, and John S. Seitz, "New Source Review (NSR) Program Supplemental Transitional Guidance on Applicability of New Part D NSR Permit Requirements," September 3, 1992). Although the memos suggest that NSR permits issued in states that missed the revision deadline would be deemed legal by the EPA only if they reflected the substantive requirements of the 1990 CAAAs, the non-binding nature of the guidance makes its legal enforceability highly uncertain. We chose to use the NSR SIP submittal date as the treatment year since it is unclear how closely state permitting authorities followed this guidance.

geographically invariant, such as a national recession. They are unable to account for changes in demand that affect only local industries.

Although this potential endogeneity is a theoretical concern, Greenstone (2002) conducted a robustness check using lagged values of the dependent variables as controls, and found that unobserved dynamic processes were not a source of bias. Similarly, after instrumenting attainment status with air quality in upwind counties List, McHone, and Millimet (2003) found that failure to instrument did not cause substantial bias in their estimates of New York counties during the 1980s.

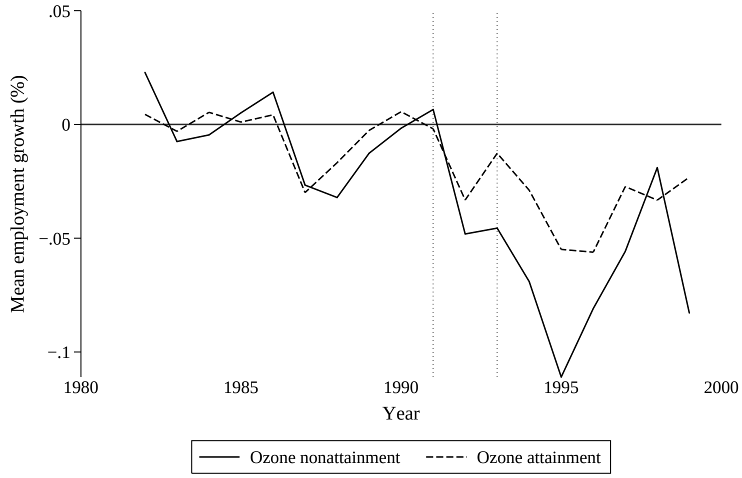
We believe that this issue is even less of a concern in the context of our study. Changes in ozone classifications and designations during our study period are primarily due to statutory changes in the 1990 CAAAs, not changes in monitoring data. In the years following the 1990 CAAAs, there were three types of attainment status changes. First, the boundary of any Serious, Severe, or Extreme non-attainment area in an MSA was expanded to include the entire MSA (i.e., all other counties within the MSA, even if they met the current standard). Second, the creation of the OTR caused attainment counties in affected states to be regulated as Moderate non-attainment areas. Thus, almost all counties that switched from attainment in 1990 to non-attainment immediately afterwards received the new designation because of their MSA or the OTR, not because of a change in local air quality.[24] Finally, all areas in non-attainment prior to 1990 were regulated under Subpart 1. In the years following the 1990 CAAAs, almost all these areas changed to one of the new ozone classifications. Although the classification itself depended on local air quality (in the 1987-1990 period), the change in classification was due to the statute, not a change in local air quality. An Extreme non-attainment area based on 1987-1990 monitoring data, for example, could have had either a decreasing, increasing, or stable historical air quality trajectory in previous years. Therefore the type of unobserved dynamic process suggested by List, McHone, and Millimet (2003) is unlikely to be generally responsible for this change in ozone regulation from Subpart 1 to Extreme.

5.2 Difference in Difference Estimator

We seek to estimate the causal effect of new ozone regulations on relative growth in labor demand. As discussed in detail above, the change in ozone attainment status due to the 1990 CAAAs imposed varying degrees of regulatory stringency on power plants in non-attainment areas (see Figure 1). However, plants in attainment areas may be systematically different than plants in non-attainment areas. Thus attainment status may be correlated with a simple OLS error term, resulting in bias. To help control for systematic differences in power plants in attainment and non-attainment areas we first follow the literature (Becker and Henderson, 2000; Greenstone, 2002; Walker, 2011) and adopt a DiD estimator. This estimator has the advantage of differencing out any pre-treatment existing differences in the treated and untreated groups to reduce selection bias, while also controlling for other potentially confounding factors that change around the time of the CAAAs. Our DiD estimator measures the difference in the change in the average employment outcome post and pre policy for the treated and untreated groups. However, this estimator requires the strong identifying assumption that, without the treatment, the average outcomes for the treated and untreated groups would have followed analogous paths over time.

[24]To our knowledge, Sunland Park, New Mexico, which became a Marginal non-attainment area in 1995 based on 1992-1994 monitoring data, is the only exception to this rule (60 FR 30789). Several areas did come into attainment in the mid-1990s, however.

Figure 2: Average Plant-level Employment Trends, by 1991 Ozone Designation



Sources: EIA, FERC, 58 FR 56694.
Notes: Nonattainment includes Ozone Transport Region.

Abadie (2005) shows that this assumption may be not be plausible if pre-treatment characteristics influence the likelihood of being treated. This "common trends" assumption can be investigated using data from several time periods, ideally many time periods, before the change in ozone regulations. Figure 2 plots employment trends for our treatment and control groups for 10 years prior to 1991 ozone regulations under the CAAA and 9 years after. The trends in average employment growth prior to the new ozone regulations are remarkably similar. A sharp divergence occurs in 1993, the second vertical line, highlighting the importance of correctly specifying the regulatory start date. These similar trends support our empirical approach, suggesting that the comparison group would likely have continued a similar trend to the treatment group in the absence of the new regulations.

5.3 Difference in Difference Results

Here we present preliminary empirical results of the EGU employment growth impacts of the 1990 CAAAs ozone regulations. We build from the standard approach in the literature; we construct a simple dummy for 1-Hour Ozone non-attainment (ignoring classification), assume the regulations take effect in 1991, and ignore the creation of the OTR. We first present results using a DiD approach, showing iteratively how addressing each of these three factors listed above impact results. We find that additional information on regulatory timing, stringency, and implementation does matter, in terms of estimating employment growth impacts.

To estimate the average effect of ozone regulation on employment growth we first use a DiD specification that utilizes a dummy for non-attainment and treatment year:

$$\text{(1)} \qquad \ln(\text{labor})_{ijt} = \delta_1 \text{Nonattain}_i + \delta_2 \text{post1990} + \delta_3 (\text{Nonattain}_i)(\text{post1990}) + \eta_i + \zeta_{jt} + \gamma_{it} + u_{ijt}$$

where ln(labor) is the natural log of employment at plant i, in NERC region j[25], and year t. The coefficient δ_3 provides an estimate of the effect of plant-level non-attainment designation from the 1990 CAAAs on plant employment growth. Nonattain_i is an indicator for whether plant i was located within an ozone non-attainment area at any time. The indicator variable post1990 equals one for all years post treatment (1991 - 1999, in our sample). This specification controls for common economic shocks to plants within a NERC region similarly by including NERC-by-year fixed effects, ζ_{jt}. It also includes a plant age as a time-varying plant-level control, γ_{it}. Time-invariant plant-level controls, η_i, include coal (percent of total BTUs) and non-attainment status, all as of 1988. In addition, we use a specification where any permanent observed or unobserved plant characteristics are controlled for with plant-level fixed effects.

We extend this specification to include information on ozone classifications from Transitional, $k = 1$, to Extreme, $k = 6$ (see Figure 1):

$$\text{(2)} \qquad \begin{aligned} \ln(\text{labor})_{ijt} \; = \; & \sum_{k=1}^{6} [\delta_{1k}\text{Class}_{ik} + \delta_{3k}(\text{Class}_{ik})(\text{post1990})] + \delta_2\text{post1990} \\ & + \eta_i + \zeta_{jt} + \gamma_{it} + u_{ijt}. \end{aligned}$$

Table 3 presents initial results from a set of six DiD specifications. The first three columns use a single indicator for ozone non-attainment, while the final three columns show how these same specifications differ after disaggregating non-attainment into the six ozone classifications. Column (1) shows the simple DiD using a dichotomous dummy for non-attainment. The DiD coefficient is listed in the top row and in this specification shows an approximately 9.6 percent gross decrease in employment growth in the post-policy period, relative to both the pre-policy period and to the control group (plants in attainment areas), and is statistically significant at the 10 percent level. Column (2) adds in plant-level observables, some of which vary over time, as well as NERC-year fixed effects. Coefficients on the plant-level observables are as expected, in that plants that were in non-attainment prior to the 1990 CAAAs had lower average employment, but coal plants (given by coal-percent in 1988), older plants, and those with larger capacities, all had higher average employment, and are all statistically significant at the 1-percent level. The DiD coefficient, in the first row, has increased a bit in magnitude, to 9.9 percent, and is statistically significant at the 5-percent level. Finally, column (3) adds plant-level fixed effects, and the average treatment effect, the DiD coefficient of -7.5 percent, declined from the prior specification, in magnitude, and is also significant at the 5-percent level. Recall from Table 1, that the average employment at a plant located in a non-attainment area, as of 1991, was 171 employees. This estimate implies a reduction in growth of about 13 employees per plant for those located in non-attainment areas relative to those in attainment areas, over the post-policy time period.

Columns (4), (5), and (6) repeat the same specifications as columns (1) - (3), but replace the non-attainment dummy with six ozone classification dummies. Results in column (6), our preferred specification, indicate that in general, the negative effect of non-attainment on employment growth increases with the level of stringency. Across classifications, most have negative coefficients, apart from Marginal, which has a small, positive, but insignificant point estimate. We find that the negative employment growth effect is only statistically significant for areas categorized

[25] Electricity demand faced by an individual plant is likely determined more so by NERC region than within county, due to transmission and wholesale market structure.

as most-stringent, specifically Serious and Extreme. The coefficient on Serious implies a relative reduction in growth of 15 employees per plant, whereas Extreme implies a relative reduction in average growth of 21 employees per plant, over the post-policy time period.

Table 4 repeats the same six specifications, but treats plants in the OTR as regulated. The treatment year is 1991. Including the OTR causes 20 plants in our sample to shift into non-attainment, at a classification and stringency level of at least Moderate. We create a seventh "OTR" classification to distinguish those plants whose status changed due to the OTR. These initial results suggest that incorporating information on the OTR only slightly impacts the magnitude of the coefficients, while not altering the patterns of signs and statistical significance. In column (3), the DiD coefficient of -8.1 percent implies a relative reduction in average growth of 14 employees. Using detailed information on classifications, instead, results in significant coefficients for the most-stringent classifications: Serious, Severe, and Extreme, with implied relative reductions of 16, 14, and 21 employees in plant-level employment growth, respectively.

Tables 5 and 6 explore how timing affects the estimated coeffcients, by repeating the specifications shown in Tables 3 and 4, but changing the policy year from 1991 to 1993. The pattern of signs and significance are similar in Tables 5 and 6, but the magnitudes vary slightly. In Table 5, without the OTR, Moderate, Serious and Extreme classifications are significant, and those estimates imply relative declines of 20, 15 and 20 in average plant-level employment growth, respectively. When the OTR is incorporated in Table 6, the pattern of signs is similar across specifications, but the magnitudes and pattern of significance is slightly different. The coefficient in column (3), for the DiD using the dichotomous variable for non-attainment, is -10.4 percent, implying a relative decline in growth of approximately 18 employees at the plant-level. Column (6) disaggregates this effect by ozone classification. The coefficients for the more stringent classifications are significant and negative, starting with Moderate, including OTR, through Extreme. The plants in the OTR are negatively affected, implying a relative reduction in growth of 22 employees at the average plant. In addition, the Moderate classification coefficient implies a relative growth reduction of 22 employees per plant-level average, Serious implies 17, Severe implies 17, and Extreme implies 21 employees. Based on this set of initial results, it appears that timing (1993 versus 1991), implementation (with and without the OTR), and stringency (increasing according to classifications) do matter for estimating employment growth impacts.

5.4 Matching Estimator

DiD estimation is most suitable when the treatment is random, or observable characteristics can be used to adjust for selection into treatment. However, as we noted above, power plants are not randomly assigned to attainment and non-attainment areas. Furthermore, power plants in our DiD control group may not be entirely similar, based on average observable characteristics, to those in our treatment group (see Table 1), thus our DiD may still be biased. Rubin (2008) notes that it is possible to approximate a randomized experiment by selecting a suitably-matched control group (here, power plants in ozone attainment areas) to eliminate or at least reduce this bias. To ensure we obtain (approximately) unbiased estimates we need to make certain as much as possible that newly regulated entities are not systematically different from the control group (Stuart and Rubin, 2008). In our case, we can reduce selection bias due to differences in observable covariates by choosing a control group with comparable covariate distributions to the power plants in non-attainment areas (Stuart, 2010). To choose such a control group we use a version of the propensity score matching (PSM) estimator developed by Rosenbaum and Rubin (1983). In keeping with the idea of replicating as close a possible a randomized experiment we again employ a DiD on our matched data. Furthermore, as Stuart and Rubin (2008) note, "matching methods are not designed to 'compete' with modeling adjustments such as linear regression, and in fact, the two methods have been shown to work best in combination."[26] However, as Imbens (2004) notes this approach could be less efficient (e.g., lead to greater sampling variance due to smaller sample sizes), as it eliminates some observations from the control group, and weights some more than others. This loss in efficiency is the tradeoff for reducing potential bias.

There are four key steps to implementing the PSM estimator (Caliendo and Kopeinig, 2008). It is necessary to (i) estimate the propensity score, (ii) choose a matching algorithm, (iii) establish an appropriate region of common support to ensure observations in the control group are sufficiently similar to the treatment group to make them appropriate points of comparison, and (iv) assess match quality by determining if the distribution of the covariates used to estimate the propensity score is the same in the treated and control groups.

We employ Stata's `psmatch2` algorithm, developed by Leuven and Sianesi (2003), to estimate the propensity score and produce our matched control group. The top panel of Table 7 presents the results of the first stage Probit model that we use to estimate our propensity score. Our dependent variable, non-attainment, is an indicator variable equal to one if the plant is in an non-attainment ozone area in 1991. To produce a control group with no observed statistical differences from our treated group it is important to include all variables that are expected to be related to our treatment, ozone non-attainment, and plant-level employment. To that end, we include percent of BTUs produced from burning coal, log generating capacity, plant age, a dummy variable indicating whether the plant was regulated during phase 1 of the SO_2 Trading Program (created by Title IV of the 1990 CAAAs), and a measure of how far the plant is from the Powder River Basin, which produces low sulfur coal.[27]

To select our control group we begin with the most straightforward matching method, single nearest-neighbor matching, in which each treated observation is paired with the control observation with the closest (in absolute value) propensity score (Dehejia and Wahba, 1999). As unmatched power plants are eliminated, the matching method isolates a sub-sample of non-regulated power plants that more closely resembles the regulated power plants in terms of pre-1990 CAAAs observable attributes. We augment the basic matching routine with a caliper of 0.1 to ensure that only power plants in (or close to) the common support are included as controls (Stuart, 2010). Finally, we employ matching with replacement which can often reduce bias because control units that are good matches for multiple treated individuals can be used numerous times (Dehejia and Wahba, 1999).

The bottom panel of Table 7 presents the estimated mean differences between the matched treatment and control group as well as the p-values for the null hypothesis that the means are equal. We also present the percent reduction of the covariate bias due to our matching routine. In all cases, there were significant differences in the mean values of covariates before we performed our matching routine. However, after matching there were no remaining significant differences in the mean values of any of the covariates, indicating we have a good "balance" between our

[26]Heckman, Ichimura, and Todd (1997); Heckman et al. (1998), and List, McHone, and Millimet (2003) employ a similar matching DiD approach.

[27]We are currently exploring other plant-level and county-level variables to include in our first stage Probit model.

treatment and control groups. In other words, the matched control group is more similar to our treatment group than the unmatched control group, therefore our DiD results will be approximately unbiased estimates of the true effect. Furthermore, the results show that our matching routine has substantially reduced the bias of our estimates due to differences in observed covariates.

5.5 Difference in Difference with Matching Results

Tables 8 and 9 present initial results using a matching technique to refine the previous DiD estimates. Table 8 presents results for 1991 without the OTR, whereas Table 9 includes OTR and uses the 1993 start date. The first three columns of Table 8 use the dichotomous indicator for ozone non-attainment, while the final three columns show how these same specifications differ once we disaggregate non-attainment into the ozone classifications defined by the 1990 CAAAs. Estimates in Table 8 follow a similar pattern for signs as Table 3. However, it has lower magnitudes generally, apart from the coefficient on Extreme in column (6) which is larger and still significant. In addition, the coefficient on the dichotomous non-attainment variable is no longer significant in any specification.

Table 9 presents results for matching using 1993 and with the OTR. We find that including OTR and using 1993 affects the results, in terms of magnitude and significance. First note that the dichotomous non-attainment indicator is insignificant in all specifications. Column (6), our preferred specification, shows a different pattern of significance, but not sign, than the companion results without matching, in Table 6. Using matching to refine the control group leads to the most-stringent classifications, Serious, Severe, Extreme, and the OTR, being significant only at the 10 percent level. The stringent classifications of Serious, Severe, and Extreme imply relative employment growth declines of 17, 16, and 24, respectively. We note that the point-estimate in this specification is strongest for those plants in Extreme areas, and those that were shifted into non-attainment because of the OTR. OTR plants were not only newly subject to the set of regulatory actions for the Moderate classification, but they also had to continue to meet requirements for plants in attainment areas, such as PSD requirements.

6 Next Steps

In the next version of this draft, we plan to explore the following extensions: we will include specifications with time-varying non-attainment and classification status, specifically taking into account the dates in which states actually submitted NSR SIPs. The distinction between when the non-attainment classifications were defined and listed, in 1991, to when states began to implement their NSR rules, which occurred over a lengthier time later in our sample, with lots of variation in timing, fits potentially well with an intention to treat framework. The 1991 listing can be viewed as the intention to regulate, while the actual regulation was implemented at a later time, with that length of time varying greatly across states. We will also differentiate between plants in counties that switched into non-attainment from attainment (due to their MSA or the OTR), and those that switched from being regulated under Subpart 1 to one of the new classifications. In addition, we're interested in exploring matching at the county-level, and controlling for other confounding factors such as electricity sector deregulation in the 1990s. Finally, we intend to further explore key issues that would enable an estimation of net, rather than gross, employment growth changes, such as considering inter-temporal and geographic spillovers. For example, did the 1990 CAAAs induce expansion activities at new plants, prior to announced compliance dates? Did electricity generation shift within NERC regions towards areas with less stringent ozone regulations?

7 Conclusion

Based on these initial results, we find that incorporating additional detail and information on regulatory stringency, timing, and implementation do matter for estimating employment growth effects of the 1990 CAAAs ozone regulations. Relative to previous work, these extensions indicate that impacts were focused within the most-stringently regulated classifications and the newly-defined OTR, and that overall, the effects are small. We emphasize that the empirical techniques utilized here allow only for estimates of relative differences in growth between groups, and do not allow for estimates of absolute impacts. For example, our preferred specification for the matching DiD shows that the new ozone classifications are tied to a relative decline in employment growth at the average plant in the most stringently regulated areas (with Extreme having the largest coefficient, in absolute value) and in newly regulated areas (OTR). However we cannot determine if that relative growth difference is because employment growth in attainment plants was declining at a slower rate, or even increasing. Moreover, we cannot ascertain whether the observed impact is due to regulations slowing growth in non-attainment areas, increasing growth in attainment areas, or some combination. These estimates are simply comparisons between two groups, and are therefore gross estimates of growth changes, and do not allow for and conclusions regarding net growth effects overall.

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Table 1: Plant Characteristics by Ozone Designation, 1989 and 1991

	1989		1991	
	Mean	Std. Dev.	Mean	Std. Dev.
Employment				
Attainment	163	142	164	143
Non-attainment	178	129	171	120
Total	169	137	167	133
Percent coal-fired BTU				
Attainment	72	44	72	44
Non-attainment	46	47	46	47
Total	61	47	61	47
GWh utilization				
Attainment	3.6	3.7	3.6	3.8
Non-attainment	3.3	3.4	3.0	3.4
Total	3.4	3.6	3.3	3.6
MW capacity				
Attainment	797	673	798	672
Non-attainment	867	700	858	698
Total	826	684	823	683
Plant Age				
Attainment	25	14	27	14
Non-attainment	33	13	34	13
Total	28	14	30	14
Number of Plants				
Attainment	287		288	
Non-attainment	208		209	
Total	497		497	

Sources: EIA, FERC, Federal Register, EPA's Green Book, McGraw-Hill Platts.
Note: Attainment areas in the Ozone Transport Region are here classified as non-attainment.

Table 2: Plant Characteristics by Ozone Classification, 1991

	Transitional	Marginal	Moderate	OTR	Serious	Severe	Extreme
Employment	166	198	201	184	111	180	98
	(182)	(133)	(133)	(73)	(91)	(110)	(43)
Percent coal-fired BTU	42	69	70	85	8	40	0
	(48)	(44)	(45)	(34)	(26)	(45)	(0)
GWh utilization	3.2	4.3	3.6	4.6	1.8	2.5	1.1
	(3.5)	(3.9)	(4.0)	(3.7)	(2.6)	(2.9)	(1.4)
MW capacity	864	958	928	932	664	857	777
	(673)	(742)	(755)	(732)	(566)	(718)	(634)
Plant age	31	30	34	37	35	35	37
	(12)	(16)	(14)	(15)	(13)	(13)	(8)
Total plants	18	19	42	20	28	69	13

Sources: EIA, FERC, EPA's Green Book, 58 FR 56694, McGraw-Hill Platts.
Note: Attainment areas and Marginal non-attainment areas, according to EPA's Green Book, in the Ozone Transport Region are here classified as OTR.

Table 3: Regression Results, 1991 Treatment without OTR

	Log employment					
	(1)	(2)	(3)	(4)	(5)	(6)
Non-Attainment×post treatment	−0.096*	−0.099**	−0.075**			
	(0.050)	(0.045)	(0.032)			
Transitional×post treatment				−0.151	−0.145	−0.114
				(0.132)	(0.092)	(0.091)
Marginal×post treatment				−0.006	0.034	0.032
				(0.104)	(0.077)	(0.050)
Moderate×post treatment				−0.058	−0.112	−0.064
				(0.092)	(0.088)	(0.077)
Serious×post treatment				−0.181*	−0.145	−0.134*
				(0.101)	(0.094)	(0.079)
Severe×post treatment				−0.116*	−0.065	−0.057
				(0.061)	(0.060)	(0.035)
Extreme×post treatment				−0.074	−0.230*	−0.215**
				(0.098)	(0.120)	(0.092)
OTR×post treatment						
Non-attainment	0.176***	0.636***				
	(0.043)	(0.061)				
Transitional				0.059	0.641***	
				(0.105)	(0.090)	
Marginal				0.329***	0.428***	
				(0.092)	(0.075)	
Moderate				0.370***	0.739***	
				(0.083)	(0.094)	
Serious				−0.300***	0.753***	
				(0.086)	(0.099)	
Severe				0.310***	0.965***	
				(0.052)	(0.076)	
Extreme				−0.250***	1.024***	
				(0.076)	(0.117)	
OTR						
Age		−0.011***	0.009***		−0.011***	0.009***
		(0.001)	(0.003)		(0.001)	(0.003)
Post treatment	−0.142***	−0.745***	−0.123	−0.142***	−0.816***	−0.135*
	(0.034)	(0.120)	(0.086)	(0.034)	(0.117)	(0.081)
Non-attainment 1988		−0.244***			−0.373***	
		(0.050)			(0.054)	
Percent Coal 1988		1.083***			1.132***	
		(0.024)			(0.025)	
Constant	4.748***	4.723***	4.493***	4.748***	4.792***	4.501***
	(0.029)	(0.111)	(0.091)	(0.029)	(0.107)	(0.091)
NERC×Year fixed effect	no	yes	yes	no	yes	yes
Plant fixed effect	no	no	yes	no	no	yes

Notes: Balanced panel with 5,878 plant-year observations. Robust standard errors. Ozone classifications according to EPA's Greenbook. Transitional includes Submarginal.

Table 4: Regression Results for 1991 Treatment with OTR

	Log employment					
	(1)	(2)	(3)	(4)	(5)	(6)
Non-Attainment×post treatment	-0.100^{**}	-0.104^{**}	-0.081^{**}			
	(0.049)	(0.047)	(0.034)			
Transitional×post treatment				-0.167	-0.160	-0.126
				(0.142)	(0.102)	(0.101)
Marginal×post treatment				0.041	0.068	0.066
				(0.135)	(0.087)	(0.062)
Moderate×post treatment				-0.062	-0.115	-0.067
				(0.092)	(0.089)	(0.077)
Serious×post treatment				-0.185^{*}	-0.156	-0.147^{*}
				(0.101)	(0.096)	(0.081)
Severe×post treatment				-0.120^{*}	-0.082	-0.077^{**}
				(0.061)	(0.066)	(0.038)
Extreme×post treatment				-0.078	-0.233^{*}	-0.217^{**}
				(0.098)	(0.120)	(0.092)
OTR×post treatment				-0.102	-0.052	-0.068
				(0.075)	(0.113)	(0.059)
Non-attainment	0.192^{***}	0.422^{***}				
	(0.042)	(0.057)				
Transitional				0.006	0.515^{***}	
				(0.114)	(0.095)	
Marginal				0.272^{**}	0.303^{***}	
				(0.121)	(0.084)	
Moderate				0.381^{***}	0.630^{***}	
				(0.083)	(0.093)	
Serious				-0.289^{***}	0.646^{***}	
				(0.086)	(0.099)	
Severe				0.320^{***}	0.869^{***}	
				(0.053)	(0.077)	
Extreme				-0.239^{***}	0.900^{***}	
				(0.076)	(0.116)	
OTR				0.402^{***}	0.246^{**}	
				(0.061)	(0.101)	
Age		-0.011^{***}	0.009^{***}		-0.011^{***}	0.009^{***}
		(0.001)	(0.003)		(0.001)	(0.003)
Post treatment	-0.138^{***}	-0.735^{***}	-0.121	-0.138^{***}	-0.813^{***}	-0.139^{*}
	(0.035)	(0.120)	(0.086)	(0.035)	(0.116)	(0.080)
Non-attainment 1988		-0.029			-0.256^{***}	
		(0.043)			(0.051)	
Percent Coal 1988		1.054^{***}			1.120^{***}	
		(0.025)			(0.025)	
Constant	4.738^{***}	4.731^{***}	4.498^{***}	4.738^{***}	4.797^{***}	4.508^{***}
	(0.030)	(0.109)	(0.090)	(0.030)	(0.106)	(0.091)
NERC×Year fixed effect	no	yes	yes	no	yes	yes
Plant fixed effect	no	no	yes	no	no	yes

Notes: Balanced panel with 5,878 plant-year observations. Robust standard errors. Ozone classifications according to EPA's Greenbook. Transitional includes Submarginal.

Table 5: Regression Results for 1993 Treatment without OTR

	Log employment					
	(1)	(2)	(3)	(4)	(5)	(6)
Non-Attainment×post treatment	−0.109**	−0.108***	−0.092***			
	(0.044)	(0.038)	(0.032)			
Transitional×post treatment				−0.176	−0.160*	−0.143
				(0.124)	(0.088)	(0.101)
Marginal×post treatment				−0.033	0.021	0.011
				(0.087)	(0.066)	(0.047)
Moderate×post treatment				−0.069	−0.133*	−0.102*
				(0.074)	(0.070)	(0.060)
Serious×post treatment				−0.192**	−0.143*	−0.138*
				(0.090)	(0.081)	(0.082)
Severe×post treatment				−0.122**	−0.068	−0.060
				(0.054)	(0.052)	(0.039)
Extreme×post treatment				−0.101	−0.215**	−0.208**
				(0.096)	(0.109)	(0.104)
OTR×post treatment						
Non-attainment	0.167***	0.624***				
	(0.033)	(0.055)				
Transitional				0.049	0.626***	
				(0.083)	(0.078)	
Marginal				0.343***	0.441***	
				(0.068)	(0.061)	
Moderate				0.367***	0.733***	
				(0.058)	(0.076)	
Serious				−0.325***	0.728***	
				(0.067)	(0.084)	
Severe				0.293***	0.956***	
				(0.040)	(0.068)	
Extreme				−0.252***	0.975***	
				(0.060)	(0.097)	
OTR						
Age		−0.011***	0.009***		−0.011***	0.009***
		(0.001)	(0.003)		(0.001)	(0.003)
Post treatment	−0.176***	−0.746***	−0.117	−0.176***	−0.813***	−0.124
	(0.030)	(0.120)	(0.087)	(0.030)	(0.116)	(0.083)
Non-attainment 1988		−0.244***			−0.373***	
		(0.050)			(0.054)	
Percent Coal 1988		1.083***			1.132***	
		(0.024)			(0.025)	
Constant	4.744***	4.729***	4.369***	4.744***	4.793***	4.384***
	(0.023)	(0.110)	(0.126)	(0.023)	(0.106)	(0.125)
NERC×Year fixed effect	no	yes	yes	no	yes	yes
Plant fixed effect	no	no	yes	no	no	yes

Notes: Balanced panel with 5,878 plant-year observations. Robust standard errors. Ozone classifications according to EPA's Greenbook. Transitional includes Submarginal.

Table 6: Regression Results for 1993 Treatment with OTR

	Log employment					
	(1)	(2)	(3)	(4)	(5)	(6)
Non-Attainment×post treatment	−0.117***	−0.114***	−0.104***			
	(0.043)	(0.041)	(0.034)			
Transitional×post treatment				−0.195	−0.174*	−0.156
				(0.134)	(0.097)	(0.112)
Marginal×post treatment				0.018	0.060	0.046
				(0.112)	(0.073)	(0.057)
Moderate×post treatment				−0.075	−0.137*	−0.108*
				(0.074)	(0.071)	(0.060)
Serious×post treatment				−0.198**	−0.157*	−0.157*
				(0.091)	(0.084)	(0.083)
Severe×post treatment				−0.128**	−0.090	−0.092**
				(0.054)	(0.057)	(0.041)
Extreme×post treatment				−0.107	−0.218**	−0.212**
				(0.096)	(0.110)	(0.104)
OTR×post treatment				−0.139**	−0.074	−0.118*
				(0.068)	(0.097)	(0.072)
Non-attainment	0.183***	0.411***				
	(0.032)	(0.051)				
Transitional				−0.005	0.496***	
				(0.089)	(0.081)	
Marginal				0.292***	0.319***	
				(0.089)	(0.067)	
Moderate				0.378***	0.624***	
				(0.058)	(0.075)	
Serious				−0.314***	0.621***	
				(0.067)	(0.083)	
Severe				0.304***	0.860***	
				(0.041)	(0.068)	
Extreme				−0.241***	0.851***	
				(0.060)	(0.095)	
OTR				0.403***	0.250***	
				(0.047)	(0.077)	
Age		−0.011***	0.009***		−0.011***	0.009***
		(0.001)	(0.003)		(0.001)	(0.003)
Post treatment	−0.170***	−0.736***	−0.112	−0.170***	−0.810***	−0.127
	(0.031)	(0.119)	(0.087)	(0.031)	(0.116)	(0.082)
Non-attainment 1988		−0.029			−0.256***	
		(0.043)			(0.051)	
Percent Coal 1988		1.054***			1.120***	
		(0.025)			(0.025)	
Constant	4.734***	4.736***	4.370***	4.734***	4.798***	4.397***
	(0.023)	(0.108)	(0.126)	(0.023)	(0.105)	(0.124)
NERC×Year fixed effect	no	yes	yes	no	yes	yes
Plant fixed effect	no	no	yes	no	no	yes

Notes: Balanced panel with 5,878 plant-year observations. Robust standard errors. Ozone classifications according to EPA's Greenbook. Transitional includes Submarginal.

Table 7: Probit Regression Propensity Score

Dependent Variable: Non-attainment					
Constant		-3.248*** (0.582)			
Coal Percent 1988		-0.789*** (0.147)	Percent BTUs from coal in 1988		
Log(Name Plate Capacity)		0.279*** (0.081)	Log of plant generating capacity		
Plant Age		0.021*** (0.005)	Year minus the year the plant was constructed		
Table A		0.069 (0.167)	A dummy variable =1 if a plant was regulated during Phase 1 of the SO2 Trading Program		
Distance to the Powder		0.001*** (0.000)	Number of miles the plant is located from the Powder River Basin		
Pseudo R2 = 0.1693					
LR chi2(5) = 113.27		(P-value= 0.0000)			
N = 497					
(Robust SEs)					
Propensity Score Balance Tests					
Variable		Mean Treated	Control	P-Value -Value	Percent Biased Reduced
Coal Percent 1988	Unmatched	0.445	0.729	0.000	—-
	Matched	0.441	0.444	0.950	98.9
Log(Name Plate	Unmatched	6.405	6.330	0.001	—-
Capacity)	Matched	6.427	6.454	0.748	64.3
Plant Age	Unmatched	36.62	30.13	0.000	—-
	Matched	31.55	30.75	0.553	87.6
Table A	Unmatched	0.183	0.214	0.003	—-
	Matched	0.181	0.186	0.897	84.0
Distance to the	Unmatched	1244.9	990.5	0.000	—-
Powder River Basin	Matched	1246.2	1258.8	0.718	95.0

Table 8: Matching Regression Results for 1991 Treatment without OTR

	Log employment					
	(1)	(2)	(3)	(4)	(5)	(6)
Non-Attainment×post treatment	0.039	−0.041	−0.038			
	(0.053)	(0.051)	(0.052)			
Transitional×post treatment				−0.016	−0.069	−0.045
				(0.133)	(0.093)	(0.117)
Marginal×post treatment				0.128	0.115	0.099
				(0.105)	(0.082)	(0.083)
Moderate×post treatment				0.077	−0.073	−0.039
				(0.093)	(0.090)	(0.079)
Serious×post treatment				−0.046	−0.126	−0.144
				(0.103)	(0.098)	(0.091)
Severe×post treatment				0.019	−0.020	−0.040
				(0.063)	(0.065)	(0.047)
Extreme×post treatment				0.061	−0.278*	−0.282**
				(0.100)	(0.160)	(0.138)
OTR×post treatment						
Non-attainment	0.261***	0.459***				
	(0.044)	(0.057)				
Transitional				0.144	0.420***	
				(0.106)	(0.081)	
Marginal				0.414***	0.242***	
				(0.093)	(0.076)	
Moderate				0.455***	0.541***	
				(0.084)	(0.090)	
Serious				−0.215**	0.487***	
				(0.086)	(0.097)	
Severe				0.394***	0.704***	
				(0.053)	(0.071)	
Extreme				−0.165**	0.843***	
				(0.077)	(0.149)	
OTR						
Age		−0.011***	0.012***		−0.011***	0.012***
		(0.001)	(0.003)		(0.001)	(0.003)
Post treatment	−0.277***	−0.804***	−0.381***	−0.277***	−0.835***	−0.380***
	(0.038)	(0.083)	(0.089)	(0.038)	(0.082)	(0.089)
Non-attainment 1988		−0.265***			−0.336***	
		(0.039)			(0.042)	
Percent Coal 1988		0.929***			0.988***	
		(0.030)			(0.031)	
Constant	4.664***	4.981***	4.360***	4.664***	5.017***	4.375***
	(0.031)	(0.059)	(0.105)	(0.031)	(0.058)	(0.106)
NERC×Year fixed effect	no	yes	yes	no	yes	yes
Plant fixed effect	no	no	yes	no	no	yes

Notes: Balanced panel with 5,878 plant-year observations. Robust standard errors. Ozone classifications according to EPA's Greenbook. Transitional includes Submarginal.

Table 9: Matching Regression Results for 1993 Treatment with OTR

	Log employment					
	(1)	(2)	(3)	(4)	(5)	(6)
Non-Attainment×post treatment	0.038	−0.057	−0.055			
	(0.047)	(0.047)	(0.062)			
Transitional×post treatment				−0.031	−0.070	−0.053
				(0.135)	(0.100)	(0.146)
Marginal×post treatment				0.182	0.162**	0.148
				(0.113)	(0.081)	(0.108)
Moderate×post treatment				0.089	−0.100	−0.081
				(0.076)	(0.074)	(0.071)
Serious×post treatment				−0.033	−0.139	−0.157*
				(0.092)	(0.087)	(0.092)
Severe×post treatment				0.036	−0.076	−0.087*
				(0.057)	(0.060)	(0.049)
Extreme×post treatment				0.057	−0.230*	−0.247*
				(0.098)	(0.137)	(0.138)
OTR×post treatment				−0.097	−0.203**	−0.214*
				(0.063)	(0.089)	(0.116)
Non-attainment	0.302***	0.429***				
	(0.034)	(0.047)				
Transitional				0.102	0.370***	
				(0.090)	(0.072)	
Marginal				0.399***	0.222***	
				(0.089)	(0.067)	
Moderate				0.485***	0.539***	
				(0.059)	(0.070)	
Serious				−0.207***	0.486***	
				(0.067)	(0.078)	
Severe				0.411***	0.772***	
				(0.042)	(0.061)	
Extreme				−0.134**	0.756***	
				(0.061)	(0.114)	
OTR				0.695***	0.513***	
				(0.040)	(0.070)	
Age		−0.011***	0.012***		−0.010***	0.011***
		(0.001)	(0.003)		(0.001)	(0.003)
Post treatment	−0.334***	−0.791***	−0.331***	−0.334***	−0.833***	−0.328***
	(0.035)	(0.082)	(0.079)	(0.035)	(0.081)	(0.079)
Non-attainment 1988		−0.211***			−0.310***	
		(0.034)			(0.040)	
Percent Coal 1988		0.918***			0.981***	
		(0.030)			(0.031)	
Constant	4.627***	4.960***	4.370***	4.627***	5.006***	4.428***
	(0.025)	(0.057)	(0.113)	(0.025)	(0.056)	(0.115)
NERC×Year fixed effect	no	yes	yes	no	yes	yes
Plant fixed effect	no	no	yes	no	no	yes

Notes: Balanced panel with 5,878 plant-year observations. Robust standard errors. Ozone classifications according to EPA's Greenbook. Transitional includes Submarginal.