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Geographic Resolution in Environmental Policy: EPA's Shift from Regions to Counties Under the Clean Air Act

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ABSTRACT

Prior to 1978 EPA regulated nonattainment with the Clean Air Act using Air Quality Control Regions (AQCRs), switching to counties in 1978. This paper investigates the implications of this change for ambient pollution and manufacturing employment. We find that EPA's official AQCR nonattainment designation for total suspended particulate matter (TSP) in 1972 had no causal effect on ambient TSP. Nor do we detect robust causal evidence that being in nonattainment in the AQCR regime affected employment in pollution intensive manufacturing industries. In contrast, using an imputed definition of 1972 nonattainment based on county level monitor readings, we find evidence that nonattainment decreased ambient TSP and manufacturing employment. After 1978, when EPA officially adopted county level nonattainment designations, both ambient TSP and manufacturing employment in pollution intensive industries declined. We discuss the implications of these findings for EPA's decision regarding the geographic level at which to regulate air pollution.

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1 Introduction

A common role of government in modern, developed economies is the management of environmental externalities. Environmental externalities vary in scope from globally mixed pollutants like greenhouse gases to highly localized pollutants like heavy metals in water bodies and particulate matter in the ambient air. These differences in physical dispersion and environmental fate and transport raise important questions regarding appropriate regulatory jurisdiction and policy resolution.

Questions pertaining to jurisdiction often hinge on transboundary pollution flows. One approach is to design policy such that compliance decisions reflect the full extent of pollution dispersion. Thus, if emissions from an industry influence environmental conditions within a state or province, compliance designations are accordingly made at the state or provincial level. An alternative policy design focuses on local effects, whereby compliance decisions are made at smaller spatial scales. The obvious benefit of the former approach is capturing the full extent of the impacts of emissions. However, the larger the compliance region, the more limited is the regulator's ability to connect impacts to specific factories, industries, or economic sectors. In contrast, while the localized strategy may omit or overlook impacts from long-range dispersion, its clear advantage is the ability to link environmental outcomes to particular polluters. A priori, both approaches have strengths and weaknesses.

This paper explores these policy design issues in the context of the United States Clean Air Act (CAA). Since 1978 the U.S. Environmental Protection Agency (EPA) has regulated ambient air quality at the county level. Counties (or portions of counties) are either in attainment or out of attainment with the National Ambient Air Quality Standards (NAAQS) which are maximum allowable concentrations of ambient air pollution. Reflecting the federalist structure of much regulation in the U.S., the NAAQS are set by the EPA and implemented by states and municipal governments. Penalties for NAAQS violations may be imposed on counties out of attainment with the NAAQS. EPA's use of counties as the geographic unit for designating compliance began, however, only in 1978.

Under the 1970 CAA, prior to the 1977 amendments, NAAQS compliance decisions were not made at the county level. Rather, the EPA levied compliance decisions for Air Quality Control Regions (AQCRs) (Murphy 2017). The AQCRs were groups of contiguous counties intended to reflect airsheds. While there are over 3,100 counties in the U.S., there were 247 AQCRs, and 313 AQCR-state pairs, with each AQCR that crossed a state boundary divided into a separate AQCR-state pair. Attainment with the NAAQS was determined at the AQCR level. Thus, all counties within the same AQCR-state pair were declared in nonattainment even if only one county violated the NAAQS.

Beginning in 1978, after the passage of the 1977 amendments to the CAA, nonattainment status with the NAAQS was assigned at the county level. EPA empowered states to select compliance regions other than AQCRs, reflecting the federalist orientation of the CAA. Specifically, the 1977 amendments to the CAA enabled states to designate attainment status based on AQCRs "or any subportions of these areas. EPA advised States they could divide AQCRs into various... portions, i.e. county, subcounty, or other geographic areas as long as the area could be clearly defined in a written narrative." (USEPA 1978). Further, EPA stated that a

motivation for this substantial change was to improve the efficiency of air pollution policy. "Section 107 of the CAA [Amendments of 1977] also provided for redesignation of the existing AQCR boundaries where a State determined that the redesignated areas would promote more efficient air quality management." (USEPA 1978).

EPA's use of AQCRs to set nonattainment status prior to 1978 has important consequences for the economics literature. There is a large literature that uses nonattainment status under the Clean Air Act to measure regulatory stringency (Becker and Henderson 2000; Greenstone; Greenstone 2002; 2004; Henderson 1996; List et al. 2003) and to instrument for air pollution—specifically Total Suspended Particulates (TSP)—in studies of the impact of air pollution on health and housing values (Chay et al. 2003; Chay and Greenstone 2005; Isen et al. 2017). Greenstone (2002) examines the impact of nonattainment status on employment in manufacturing plants between 1967 and 1987 and finds that nonattainment counties lost, on average, 592,000 jobs relative to attainment counties between 1972 and 1987. Chay and Greenstone (2005) finds that TSP declined by 10 $\mu g/m^3$ in nonattainment relative to attainment counties between 1970 and 1980. To measure nonattainment status prior to 1978, these studies use air pollution monitor readings rather than nonattainment status as designated by the USEPA. An important question is whether these results would change using nonattainment status as designated by the EPA. Put somewhat differently, do key results about the impact of nonattainment status on ambient TSP and on manufacturing employment continue to hold when the official designation of nonattainment status is used?

Our Approach

We examine these questions in this paper using quasi-experimental econometric methods. First, we focus on the period from 1969 to 1976 when compliance determinations were made at the AQCR level. Specifically, we ask whether ambient TSP fell faster in counties declared out of attainment with TSP than in attainment counties. Further, we test whether being out of attainment for any of the following four criteria pollutants which were subject to the NAAQS (TSP, Carbon Monoxide (CO), Ozone (O_3) and Sulfur dioxide (SO_2)) caused employment in pollution-intensive manufacturing industries to fall in nonattainment relative to attainment counties. Over the period when EPA used AQCR designations, we do not find evidence of differential outcomes in attainment versus nonattainment counties. Specifically, using EPA's definition of nonattainment by AQCR, we find no evidence that ambient TSP fell faster in nonattainment than in attainment counties between 1969 and 1976, when the parallel trends assumption holds.[1] Nor do we find a statistically significant, causal impact of nonattainment for any of the four criteria pollutants on the ratio of pollution-intensive manufacturing employment to total employment.

We repeat these empirical tests for the period 1975 to 1988 using EPA's county-based nonattainment designations, which were assigned by EPA in 1978. Our results are very different in this context. Counties out of attainment with TSP in 1978 reduced their ambient TSP levels more than attainment counties over the period 1975-88. When considering the impact of nonattainment for each of four criteria pollutants (TSP, CO,

[1] We realize that the assumption of parallel trends cannot be proved. We say that parallel trends hold when the null hypothesis of parallel trends cannot be rejected.

Ozone and SO_2) on the fraction of employment in pollution-intensive industries from 1975 to 1988, we find a significant reduction in the fraction of employment in dirty industries out of attainment with only TSP and in pollution-intensive industries in counties out of attainment with TSP and at least one other pollutant.

We are, however, aware that the emphasis which EPA and the states placed on counties after 1978 may be reflected in the impact of the NAAQS before 1978. To test this, we examine the impact of violations of the NAAQS by monitors in individual counties on ambient TSP during the 1969-76 period. Specifically, we use Michael Greenstone (2020)'s imputation of TSP nonattainment in 1972 at the county level, as well as imputations based on alternate definitions of nonattainment using averages of monitor readings in 1971. We find that imputations of nonattainment based on monitor readings often show significant impacts of nonattainment on ambient TSP during the 1969-76 period. We also examine whether being out of attainment with either TSP, CO, Ozone or SO_2 in 1972 based on Greenstone's imputation of nonattainment had an impact on manufacturing employment between 1969 and 1976. We find that 1972 nonattainment, when defined at the county level based on monitoring data, did have a negative causal impact on manufacturing employment.

This dimension of our work extends the existing literature in three ways. First, earlier work examining this period used associational econometric models, whereas we test for causal policy effects. Second, we use a different data source for manufacturing employment. And, as a function of these innovations, we find larger effects of the CAA on employment in pollution-intensive manufacturing sectors extending over the period from 1969 to 1988. Last, the impacts we detect appear to derive from TSP nonattainment, whereas earlier work found that CO and Ozone nonattainment induced job loss (Greenstone 2002).

Our Data

We investigate the impact of nonattainment status on ambient TSP and manufacturing employment by assembling data on TSP monitor readings from 1969 through 1988 and data on manufacturing employment at the county level over the same period from County Business Patterns data (Eckert et al. 2020; Eckert et al. 2022). We construct county-level estimates of annual average ambient TSP using a balanced panel of monitors in 309 counties from 1969-76 and a balanced panel of monitors in 402 counties from 1975-88. We use these to estimate difference-in-differences models and event studies to gauge the impact of nonattainment status on ambient TSP.

To analyze the impact of nonattainment status on manufacturing, we examine the impact of being out of attainment for each of the four criteria pollutants (TSP, CO, Ozone and SO_2) on the ratio of dirty manufacturing employment to total employment. We estimate the impact of 1972 nonattainment on employment over the 1969-76 period and 1978 nonattainment on employment over the 1975-88 period. We do this using border-pair analysis and also by estimating difference-in-differences models and event studies. Because a county can be out of attainment for more than one pollutant, we estimate models that control for nonattainment status for multiple pollutants. For the period 1969-76 we do this using EPA's definition of nonattainment in 1972 based on AQCRs. We also examine the effect of 1972 nonattainment at the county level based on monitoring data.

Our Results

This paper makes three contributions to the literature. First, between 1969 and 1976 when EPA used AQCR designations, we do not find causal evidence of differential changes in TSP concentrations in attainment versus nonattainment counties. Specifically, using EPA's definition of nonattainment by AQCR, we find no evidence that ambient TSP fell faster in nonattainment than in attainment counties, when the parallel trends assumption holds. In the period after 1978, when nonattainment designations changed from AQCRs to counties, we report robust and significant evidence that the CAA lowered ambient pollution levels. Ambient TSP levels in nonattainment counties fell by between 6 and 7 $\mu g/m^3$ more than in attainment counties over the 1975 to 1988 period.

Second, and in accord with the result for TSP, we do not detect causal evidence that pollution-intensive manufacturing employment (expressed as a fraction of total manufacturing employment) fell in nonattainment counties during the AQCR-based regime, from 1969 to 1976. This lack of causal evidence encompasses TSP as well as nonattainment for CO, Ozone, and SO_2 in all but one specification. When considering the impact of nonattainment for each of four criteria pollutants on the fraction of employment in pollution-intensive industries from 1975 to 1988, we find a significant reduction in the fraction of employment in these dirty industries of 0.9% in counties out of attainment with only TSP and a 1.1% reduction in the fraction of employment in dirty industries in counties out of attainment with TSP and at least one other pollutant.

Third, as stated above, the literature imputed nonattainment status prior to 1978 by declaring a county out of attainment if its ambient monitor readings exceeded the maximum levels stated in the NAAQS (Greenstone 2002; Chay et al. 2003; Chay and Greenstone 2003; Isen et al. 2017). We use this definition of nonattainment to test for differential regulatory treatment of counties within the AQCRs. We report evidence that ambient TSP levels fell in counties that had ambient TSP readings above the NAAQS, relative to counties with ambient TSP levels below the NAAQS. This may suggest that regulatory efforts targeted counties with high TSP levels. We also find a significant reduction in the fraction of employment in pollution intensive manufacturing industries from 1969 to 1976 of 0.5% in counties out of attainment for only TSP, between 0.5% and 1% in counties out of attainment for either CO, ozone or SO_2, and a 1% reduction in counties out of attainment for TSP and at least one other pollutant.

The results presented in this paper for the 1969-76 period, coupled with those in the published literature, suggest that the EPA likely targeted dirtier counties in its enforcement efforts. This is borne out by our findings of the impact of imputed 1972 nonattainment based on monitor readings on manufacturing employment. These causal results from 1969 to 1976, coupled with impacts from 1975 to 1988 suggest job losses on the order of 800,000. This estimate is substantially larger than the 592,000 jobs lost estimated in Greenstone 2002.

We contend that these findings shed light on an important policy decision at EPA: to move from regulating air quality at the AQCR level to the county level. The intuitive appeal of AQCRs is that they mimic air-sheds—areas where emissions from multiple sources mix to determine ambient air quality. Although useful from the perspective of dispersion and atmospheric chemistry, AQCRs pose problems from a regulatory perspective.

Faced with newly established constraints on ambient pollution, regulators targeted abatement in the most polluted counties within the AQCRs. The resulting air quality improvements were concentrated in these counties, as our results below show.

We note an additional limitation to airshed-based regulations. Provisions of the 1977 amendments to the CAA would have been very costly to enact had the AQCR designations been retained beyond 1978. This is illustrated in Figure 1a, which shows that two-thirds (or 2069) of all counties in the coterminous U.S. were declared out of attainment for TSP in 1972, based on AQCR designations. Under the 1977 amendments, new firms that were major sources entering counties out of attainment with the NAAQS faced higher compliance costs than new sources in compliant counties. Specifically, new facilities in nonattainment areas were required to install the lowest achievable emissions rate (LAER) technology and to offset their emissions by buying rights to emit pollution from existing sources (Shapiro and Walker 2025). Since the focus of these provisions lay clearly on pollution hot spots, it would not have made sense to apply them to nonattainment areas as defined by AQCRs.

In summary, we believe that our findings have implications for the geographic resolution at which air pollution is regulated and the stringency with which it is regulated. While the management of pollution externalities according to the area over which concentrations are affected has a strong scientific basis, we note several concerns with this approach. First, regulators facing incentives to comply with ambient standards tend to target high pollution areas. The result of this, for the case of air pollution in the U.S., was heterogeneity within the airshed both in terms of air quality changes and compliance costs. Second, this intra-airshed variation, despite uniform compliance designations, may obscure empirical inferences about policy effectiveness. Finally, airshed-based compliance determinations limit the ability of regulations to nudge economic development toward compliant geographies especially if, as was the case in the U.S. prior to 1978, most areas are noncompliant.

The remainder of this paper is structured as follows. Section 2 summarizes salient facts about EPA's regulation of air pollution under the 1970 CAA and the 1977 CAA amendments. Section 3 describes our data, econometric methods, and the results of our analysis of the impact of nonattainment status on ambient TSP. In Section 4 we report the impact of nonattainment status on manufacturing employment. Section 5 summarizes our results and concludes.

2 Regulation of Ambient Air Pollution Under the 1970 and 1977 Clean Air Acts

The 1970 CAA required EPA to establish ambient air quality standards for common (or "criteria") air pollutants, and required states to draft state implementation plans (SIPs) to describe how they would come into compliance with these standards (USEPA 1973). In 1971 EPA issued National Ambient Air Quality Standards (NAAQS) for TSP, CO, Nitrogen dioxide, SO_2, and Ozone (USEPA 1971). The Agency also defined 247 AQCRs, spanning the continental US, Alaska and Hawaii, the Virgin Islands and Guam (USEPA 1972b).

Each AQCR was a group of contiguous counties located in the same airshed. There were 313 AQCR-state pairs, with each AQCR that crossed a state boundary divided into a separate AQCR-state pair.

In May of 1972 counties within each AQCR were determined to be in attainment or out of attainment with each of the criteria pollutants (USEPA 1972a). Attainment status was determined based on 1971 monitor readings; however, TSP monitors operated in only 765 counties in 1971. EPA also used air quality modeling to determine attainment status. All counties within the same AQCR-state pair were assigned the same attainment status. Figure 1a shows the boundaries of the AQCRs in the continental US and their attainment status for TSP in 1972. When AQCRs are mapped to counties, 2,069 counties were designated as TSP nonattainment counties and 1,044 as attainment counties.[2]

Nonattainment status for other pollutants in 1972 is shown in Table 1 (Maps showing nonattainment counties for these pollutants appear in Appendix Figures A1a–A3a). In 1972, 997 counties were declared out of attainment for SO_2, 651 counties for Ozone and 271 counties for CO. Many counties were out of attainment for multiple pollutants. While 2,069 counties were designated as out of attainment for TSP, 1,189 counties were out of attainment for TSP and at least one other pollutant. There were 932 counties in attainment with all four pollutants. Beginning in 1978, assignment of attainment status was conducted at the county level. Figure 1b shows the 433 counties designated as nonattainment for TSP in 1978 (Maps showing nonattainment counties for other pollutants appear in Appendix Figures A1b–A3b). The number of counties designated as out of attainment for TSP and SO_2 fell sharply when nonattainment (NA) status was assigned county by county—from 2,069 to 433 for TSP and from 997 to 98 for SO_2 (see Table 1). The number of counties declared out of attainment also declined for CO though by a much smaller margin than for SO_2 and TSP (from 271 to 167). Only in the case of Ozone nonattainment did the number of counties increase, from 651 to 685. This demonstrates that for two key pollutants—TSP and SO_2—the number of counties subject to the consequences of NA under the 1977 CAAA fell significantly.

In addition to changing the resolution of nonattainment designations, the 1977 CAAA strengthened air quality regulations in important ways that affected stationary sources in nonattainment counties. Major sources that entered or expanded operations in a nonattainment county were not allowed to increase emissions of nonattainment pollutants.[3] To avoid increases in emissions, proposed emissions increases had to be balanced by equivalent or greater reductions from existing sources. This was often achieved by purchasing offsets from existing sources (Shapiro and Walker 2025). Major sources were also required to achieve the Lowest Achievable Emissions Rate (LAER) for nonattainment pollutants. LAER is the most stringent emission limit included in the SIP of any state, or the most stringent emissions limit achieved in practice (USEPA nd).[4] As stated above, our empirical results indicate that the official nonattainment designations affected air quality and employment only after the 1977 amendments. Clearly, two aspects of the CAA changed that may have driven our findings:

[2]We are happy to share the data describing AQCR status by county upon request.

[3]A major source was a facility estimated to produce more than a threshold number of tons per year (often 100 tons) of a pollutant for which the county was out of attainment.

[4]Minor sources were not required to purchase offsets or achieve the LAER. They were subject to less stringent Reasonable Available Control Technology (RACT) standards (USEPA nd).

the stringency of the regulations governing new sources, as well as the use of counties rather than AQCRs as nonattainment units.

3 The Impact of Nonattainment on Ambient TSP, 1969-1988

3.1 The Impact of Nonattainment Status on Ambient TSP: Methods

We examine the impact of nonattainment status on ambient TSP using two balanced panels of monitors, 606 monitors in 309 counties for 1969-76 to study the impact of 1972 NA status on ambient TSP and 763 monitors in 402 counties for 1975-88 to study the impact of 1978 NA status. The need to use a balanced panel of monitors (i.e., requiring that the same monitors be in operation each year) is well established, given evidence that newly cited monitors often have lower pollution readings than existing monitors (Cropper et al. 2023; Grainger et al. 2019; Muller and Ruud 2018).[5] We examine the impact of nonattainment status in 1972 using both EPA's official designation of nonattainment based on AQCRs and two imputations of nonattainment at the county level, which are based on monitor readings in 1971. We also use the designations in Greenstone (2020). The imputations based on monitor readings allow us to test whether dirtier counties were targeted during the 1969-76 period. In 1978 and thereafter, nonattainment status is based on EPA's official designation, by county. Descriptive statistics for these counties appear in Appendix Table A1. Figures A4a and A4b in the Appendix show the location of attainment and nonattainment counties in 1972 and 1978 based on EPA-designated attainment status for TSP.

To examine the impact of nonattainment status on ambient TSP, we estimate difference-in-differences and event study models for 1969-76 and 1975-88. In our difference-in-differences models, equation (1), $Post_t = 1$ for year $t \geq 1972$ or $t \geq 1978$. All of the difference-in-differences models for both periods contain county and year fixed effects. For the 1969 to 1976 period using the AQCR designations, we also include state-by-year fixed effects. Over the same period, when using the nonattainment imputations based on monitor readings, we also estimate a specification that includes AQCR-by-year fixed effects. For the 1975-88 period, when nonattainment status is defined by county, we estimate specifications that alternatively include state-by-year and AQCR-by-year fixed effects.

$$TSP_{ct} = \beta_1 Post_t \times NonAtt_c + \delta_c + \tau_t + \gamma_{st} + \epsilon_{ct}. \tag{1}$$

Table 2 shows the number of nonattainment and attainment counties for each sample based on EPA's official designation of nonattainment status and Michael Greenstone's imputation based on monitor readings. We note that by EPA's designation, only 47 of 309 counties were in attainment. Using the imputation based on monitor readings (Greenstone 2020), 184 counties were in attainment. The difference reflects the fact that all counties in the same AQCR-state-pair were labeled nonattainment even though some may not have violated the NAAQS.

[5]The fact that so few counties have the same monitor(s) in operation during this period reflects the size of the ambient monitoring network.

(Table A1 of the Appendix presents summary statistics for both groups of counties.)

Figure 2 shows the implications of the difference in the two definitions. Using the AQCR definition of nonattainment, mean TSP in nonattainment counties in 1972 was 78.85 $\mu g/m^3$, barely above the annual average TSP standard of 75 $\mu g/m^3$.[6] This is because many counties labeled nonattainment did not have ambient TSP levels above the NAAQS. In contrast, the counties with TSP levels above the NAAQS exhibited a mean TSP in 1972 of 96.90 $\mu g/m^3$.

Another difference between nonattainment counties under the AQCR and the imputation based on monitor readings is that, using the AQCR definition, nonattainment and attainment counties do not exhibit parallel trends prior to treatment. This is not surprising. The 47 counties out of the 309 that EPA characterized as being in attainment are largely rural. Their average TSP levels prior to 1972 were flat and below 60 $\mu g/m^3$. In contrast, counties labeled nonattainment by AQCR began to decrease their TSP levels prior to 1972.

Panel (b) shows that counties with monitor readings above the NAAQS had much higher pollution levels than the combination of counties officially out of attainment but with monitor readings under the NAAQS and the other attainment counties. However, the trends between these groups are parallel prior to treatment. We infer that this result occurs because the nonattainment counties with lower pollution levels (attributed to the attainment group in this case) experienced air quality reductions from adjacent, dirtier counties.

3.2 Impact of Nonattainment Status on Ambient TSP: Results

Table 3 reports the results of the regression analyses that test whether attainment status affected ambient TSP levels. These models are fit to the data in Figures 2a–2c. In columns (1) and (2) we employ EPA's official AQCR designation of nonattainment for the period from 1969 to 1976. We find statistically significant evidence that counties in nonattainment for TSP exhibited a reduction in ambient TSP levels over the 1969-1976 period. The effect size varies in magnitude between 6 and 9 $\mu g/m^3$, depending on the set of fixed effects included. Crucially, the parallel trends assumption fails to hold when using EPA's official, AQCR-based nonattainment status. Thus, we cannot interpret the effects in columns (1) and (2) as evidence of a causal relationship. In columns (3) through (5) we use Greentone's imputation of nonattainment status (Greenstone 2020). Here the effect size is somewhat smaller than in columns (1) and (2), between 5 and 6.5 $\mu g/m^3$. Further, the parallel trends assumption does hold when using the imputation of nonattainment status which comports with Figure 2b.

Table A2 in the Appendix explores multiple empirical imputations of nonattainment status based on ambient TSP readings. Columns (1) through (3) employ the (Greenstone (2020)) measure. Columns (4) through (6) impute nonattainment status to counties that exhibit a geometric mean TSP level in 1971 above the NAAQS using our balanced panel of monitors. Columns (7) through (9) repeat the design in (4) through (6) but nonattainment is imputed based on the monitor with the highest TSP reading in each county exceeding the NAAQS. All of the coefficients are negative and statistically significant at conventional levels. In only one specification does the parallel trends assumption fail to hold. We interpret these results as evidence that, in highly polluted counties, the 1970 CAA indeed induced a drop in concentrations of TSP relative to counties that

[6] This is the arithmetic average of TSP readings across all monitors in the county.

were officially in attainment, or counties in nonattainment that had observed pollution levels below the NAAQS. This suggests that abatement activities were targeted in highly polluted counties. Together with Table 3, these results do not support the conclusion that the CAA reduced TSP levels across counties within AQCRs that were officially in nonattainment. Rather, air quality improvements appear to have been concentrated within AQCRs in TSP hot spots.

To examine the impact of nonattainment status in 1978 on ambient TSP levels, we use a different group of counties. Included in this sample are the 402 counties that comprise a balanced panel of TSP monitors in operation every year between 1975 and 1988 (see Table 2); 56% of these counties were designated out of attainment with the 1978 TSP NAAQS. Trends in TSP for attainment and nonattainment counties in this group are shown in Figure 2c. The fitted DiD models for 1975-88 are reported in columns (6) through (8) of Table 3. The 1978 designation of nonattainment status reduced ambient TSP levels by 6 to 8 $\mu g/m^3$ relative to attainment counties for the 402 counties in our sample. Importantly, the parallel trends assumption holds in two of the three fitted models. Specifically, the assumption holds in the models that control for county, year and either state-by-year or AQCR by-year fixed effects, shown in columns (7) and (8). The effect sizes reported in these models are quite similar, within 10% of each other.

The preceding discussion demonstrates that the official AQCR nonattainment status in 1972 did not have a causal impact on ambient TSP. AQCR nonattainment in 1972 could, however, affect ambient TSP in later years. To test this, we estimate models for ambient TSP in the 1975-88 period with three treatment variables: being out of attainment for TSP in both 1972 and 1978 (NN), being out of attainment for TSP in 1972 but in attainment in 1978(NA) and being in attainment for TSP in 1972 but out of attainment in 1978 (AN). Counties in attainment for TSP in both years (AA) serve as controls. As shown in columns (1) and (2) of Table A7, counties that were in nonattainment only under the AQCR regime (NA) exhibit no difference in TSP relative to counties always in attainment (AA). Counties in this designation likely had low pollution levels but were designated in nonattainment status due to the coarse resolution embodied in the AQCR approach. If regulators focused enforcement on TSP hotspots, pollution levels in the NA group would likely not change prior to 1978. We interpret the equivalence of NA and AA as further evidence that regulators targeted TSP hotspots.

The fact that we do find causal evidence of a relationship between the official EPA nonattainment designation in 1978 and subsequent ambient TSP levels may reflect *either or both* the strengthening of emissions regulations under the 1977 Amendments to the CAA and the focus on counties as the unit of regulation. We cannot disentangle these two effects. We also note that the consequences of these differences in concentrations for exposures were quite likely large: the 402 counties in our balanced panel contained 54% of the US population in 1980.

As argued in Section 1, the use of AQCRs, or airshed-based nonattainment designations, has a firm grounding in the natural sciences. However, our failure to identify a causal impact of the CAA in columns (1) and (2) of Table 3, together with the results in columns (3) through (5), provide evidence that, despite the spatially-extensive AQCR nonattainment designations, abatement activities were concentrated in counties that exhibited relatively high pollution levels. This conclusion is bolstered by the results in columns (6) through (8) which reflect

outcomes after adoption of the county-based attainment designations. This change in regulatory resolution transitioned many counties from nonattainment to attainment status, and therefore *officially* focused regulatory efforts on high-pollution counties.

4 The Impact of Nonattainment on Manufacturing Employment, 1969-1988

In a seminal article, Greenstone (2002) examined the impact of nonattainment status for four criteria pollutants (TSP, CO, Ozone and SO_2) on employment in dirty, or pollution-intensive, manufacturing industries from 1967 to 1987, using plant-level data from the Annual Survey of Manufacturers . Dirty manufacturing industries were defined, for each pollutant, to be industries that were major emitters of that pollutant. Greenstone estimated that 592,000 jobs were lost in nonattainment counties over the 1972-1987 period. The largest impacts were found in counties out of attainment with CO and Ozone. As we mentioned above, for the period prior to the enactment of the 1977 Amendments, nonattainment status was approximated using monitor readings (Greenstone 2002).

We examine the effect of nonattainment status on manufacturing employment using county-level employment data over the period 1969-1988 (Eckert et al. 2020; Eckert et al. 2022). Specifically, we examine the impact of nonattainment status for TSP, CO, Ozone and SO_2 on dirty manufacturing employment using difference-in-difference (DiD) approaches. One approach (sections 4.2 and 4.3) compares the full set of treated and control counties in a standard DiD setup. The second DiD (section 4.1) restricts treatment and control counties to those that share a border. We define a manufacturing industry as "dirty" if it is classified by Greenstone (2002) as a major emitter of TSP, CO, Volatile Organic Compounds (precursors to Ozone) or SO_2.[7] Table A3 in the Appendix lists industries classified as major emitters of each pollutant, by six-digit NAICS category. Dirty manufacturing employment is defined as the union of employment in these industries.

When examining impacts on pollution-intensive manufacturing employment we normalize dirty manufacturing employment by total employment. The distribution of manufacturing employment across counties is skewed, but the use of a logarithmic transformation is not advisable (Chen and Roth 2024) in DiD analyses. We normalize by employment to assess the average treatment effects in proportional terms. This approach also facilitates causal inference as parallel trends are more likely to hold when the dependent variable is expressed in this manner, given differences in the levels of manufacturing employment between treatment and control counties.

[7] We have also examined dirty employment separately for each pollutant (e.g., dirty-TSP employment, dirty-CO employment); however, many industries are major emitters of multiple pollutants (see Table A3), leading to double counting of employment effects.

4.1 The Impact of Nonattainment Status on Manufacturing: Border-Pair Models

Our border-pair analysis estimates the impact of nonattainment status for each pollutant on the ratio of dirty manufacturing employment to total employment by comparing nonattainment counties for a particular pollutant in 1972 to adjacent attainment counties (sharing a border) over the period 1969-76. A similar comparison is made over the period 1975-88. Figures 3 shows border-pair counties for TSP in 1972 and 1978. Figures A5–A7 of the Appendix present border-pair maps for CO, Ozone and SO_2.

The advantage of the border-pair analysis is that each nonattainment county is matched with a proximate attainment county, thus controlling for unmeasured factors that may affect shared labor markets. In our border-pair analysis we measure the impact of each pollutant individually on the ratio of dirty manufacturing employment to total employment.

EPA's definition of nonattainment by AQCR has implications for the number of nonattainment counties that share borders with attainment counties in 1972. Many nonattainment counties are not adjacent to attainment counties, as a comparison of Figures 1a and 3a illustrates. Only 657 out of 2,069 counties out of attainment for TSP in 1972 share a border with an attainment county. This yields 1,308 unique border-pairs. The situation is similar for Ozone and SO_2 nonattainment counties: only 380 out of 651 counties out of attainment for Ozone and 435 out of 997 counties out of attainment for SO_2 share a border with an attainment county.

The situation is different when attainment status is defined by county. In 1978, 90 percent or more of counties out of attainment with TSP, CO and SO_2 were adjacent to attainment counties; on average, each county in nonattainment was adjacent to between 3 and 4 attainment counties.[8]

Table 4 shows key employment statistics for TSP border-pairs in both periods of our analysis, 1969-76 for 1972 nonattainment status and 1975-88 for 1978 nonattainment status. (The corresponding tables for CO, Ozone and SO_2 are Tables A4–A6 which are found in the Appendix.) Nonattainment counties are, on average, larger in terms of population and have larger labor markets. Further, nonattainment counties have more workers employed in dirty industries than attainment counties. The ratios of dirty to total employment are higher in nonattainment counties .

Our regression specification for the border-pair analysis is shown in (2):

$$y_{ct} = \beta_1 Post_t \times NonAtt_c + \delta_c + \tau_t + \gamma_{pt} + \epsilon_{ct}, \tag{2}$$

which is similar to equation (1) but we restrict our sample to pairs of nonattainment and attainment counties that share the same border. The dependent variable is the ratio of dirty manufacturing employment to total employment (y_{ct}). Our border-pair model contains county (δ_c) and year (τ_t) fixed effects and county pair-by-year fixed effects (γ_{pt}).

Table 5 presents the results from applying equation (2) to the sample of border-pair counties. The p-values reported in the bottom row correspond to a test of the null hypothesis of parallel trends. Columns (1) through

[8]This is not, however, true for Ozone. Counties out of attainment for ozone in 1978 are clustered in the Northeast and Middle Atlantic states, or in California. (See Figure A2 in the Appendix.)

(4) focus on the years during which nonattainment status for each of the four criteria pollutants was determined using the AQCR approach. The results indicate that counties in nonattainment for TSP, CO, and Ozone in 1972 had a lower ratio of dirty to total employment over the period 1969-76 relative to counties in attainment. For SO_2, the coefficient is zero. However, only the impact of nonattainment for CO is statistically significant. In the case of TSP, the assumption of parallel trends is rejected, whereas this assumption holds for Ozone, CO, and SO_2.

The situation is quite different for the 1978 nonattainment status. In columns (5) through (8), the models for each of the four criteria pollutants show a statistically significant negative impact of nonattainment status on the ratio of dirty manufacturing employment to total employment. This effect is largest for SO_2 (1.4%) and TSP (0.9%). Moreover, for SO_2, TSP, and Ozone, the effect of nonattainment status on employment is causal, as the parallel trends assumption holds in each case. In contrast, though nonattainment status for CO also appears to adversely impact employment in dirty manufacturing industries, the parallel trends assumption does not hold. We emphasize that these coefficients must be interpreted with some caution. The models focusing on the impact of nonattainment status for each pollutant separately do not control for the attainment status for other pollutants.

Much like the results for ambient TSP presented above, these results suggest that when regulation was targeted by county, it adversely impacted employment in dirty manufacturing industries. To further test this hypothesis, Table 6 repeats the border pair analysis for 1972 TSP nonattainment using three definitions of nonattainment based on air quality monitor readings. Column (1) is identical to column (1) from Table 5 for comparison. Column (2) uses Greenstone's imputation to designate nonattainment counties. The second, shown in column (3), designates a county as nonattainment if the geometric mean of all TSP readings in 1971 exceeded the NAAQS. The third, column (4), designates a county as nonattainment if the geometric mean of readings from dirtiest TSP monitor in 1971 exceeded the NAAQS. As shown in Table 6, all three definitions based on monitor readings indicate that nonattainment with TSP in 1972 reduced the ratio of dirty to total manufacturing employment by 0.7-0.8%. Further, the parallel trends assumption holds in each case. This suggests that attempts to reduce TSP were targeted at nonattainment counties based on monitoring readings, not AQCR status.

In this paper, our central argument is the use of AQCRs as nonattainment designations did not align with implementation of activities to achieve NAAQS compliance. Recall that Table 3 showed this using TSP levels. Table 5 and 6 support this argument by providing consistent evidence that employment in pollution-intensive industries contracted relative to total employment only when nonattainment designations reflect the county level of resolution, either based on 1978 nonattainment status or imputed 1972 nonattainment status.

4.2 The Impact of Nonattainment Status on Manufacturing: Single-Pollutant DiD Models

We next consider DiD models that incorporate all nonattainment counties. In the first set of models we focus on each pollutant, one-at-a-time. In these analyses, counties in attainment for each pollutant in a given year comprise the control group. In section 4.3, we present models which control for multiple pollutants. Since these samples contain far more counties than the border-pair analysis, we briefly discuss summary statistics here.

Table 4, panel (a) indicates that, according to the AQCR definition of TSP nonattainment in 1972, nonattainment counties were, on average, more populous and had larger labor markets than counties in attainment. This is true for total employment levels and for employment in dirty industries. Further, the ratio of employment in dirty industries to total employment was 50% larger in nonattainment counties.

In panel (b) of Table 4, which uses the 1978 county-level attainment designations, it is clear that nonattainment counties were also more populous and had larger labor markets than counties in attainment. Furthermore, the difference between attainment and nonattainment counties was more pronounced. This is intuitive since, under the county-level nonattainment designations, counties out of compliance with the NAAQS tended to be urban core counties; these were more densely populated areas with larger labor supplies. Our regression specification for the one-pollutant-at-a-time models is shown in (3):

$$y_{ct} = \beta_1 Post_t \times NonAtt_c + \delta_c + \tau_t + \gamma_{st} + \epsilon_{ct}, \tag{3}$$

The specification is similar to equation (2), but we include all nonattainment counties in this model. These models contain county and year fixed effects and either state-by-year or AQCR-by-year fixed effects.

Table 7 reports the results of estimating these models for the 1969-76 period (in panels A and B) and the 1975-88 period (in panel C). As in the case of the border-pair models, we use two definitions of nonattainment in 1972: EPA's AQCR designation and Greenstone's imputed definition (see Table 1). The results are similar to those in the border-pair models, even though both the treatment and control groups differ. Using the AQCR definitions of nonattainment (Panel A) when AQCR-year fixed effects are included parallel trends are satisfied in all models but one. However, there are only two statistically significant coefficients, and only in the model for Ozone using state-year fixed effects is the parallel trends assumption also satisfied. In contrast, when the imputed definition of nonattainment is used (Panel B) there is, for each pollutant, at least one case in which parallel trends are satisfied, and nonattainment exhibits a statistically significant, negative effect on pollution intensive manufacturing employment.

These results further indicate that there is no robust, consistent evidence that AQCR-based nonattainment for any of the four pollutants affected dirty manufacturing employment in treatment relative to control counties. However, use of the imputed definition of nonattainment does show significant negative effects on employment.

In Panel C, the analysis of county-based nonattainment status between 1975 and 1988 suggests that being out of attainment for any of the four pollutants in 1978 significantly reduced the ratio of dirty manufacturing

to total employment. The magnitudes of the coefficients are similar to those in the border-pair models in Table 5. All models satisfy the parallel trends assumption when AQCR-year fixed effects are used, and, with the exception of TSP, when state-year fixed effects are used. As in the border-pair analysis, the magnitude of the employment effect of SO_2 nonattainment is largest, followed by the effect of TSP nonattainment. However, when interpreting the total effect of nonattainment status for these two pollutants, it is critical to note that fewer counties were out of attainment for SO_2 (98) than for TSP (433). Similarly, the employment effect of Ozone nonattainment is smaller than the coefficient of TSP, yet more counties (685) were out of attainment for Ozone in 1978 than for TSP. We return to the issue of tabulated total job losses due to the CAA in section 4.3 below.

Columns (3)-(10) of Table A7 in the Appendix extend our analysis of the relationship between nonattainment status in 1978 and employment to include attainment status in the AQCR regime. The objective of this analysis is to test whether attainment status under the AQCR regime influenced outcomes after 1978. Relative to counties that were in attainment under both regimes (the control group), counties that were out of attainment under both the AQCR and the county-based designations (NN in the table) exhibit a lower ratio of dirty manufacturing to total employment for CO, Ozone, and SO_2 than control counties (shown in columns (5) through (10)). In five of six specifications the results are causal. (The negative coefficient for TSP in column (3) is not causal.) In contrast, across all pollutants, dirty manufacturing employment in counties that were in nonattainment only under the AQCR regime (shown as NA) exhibit no causal difference relative to counties always in attainment. Under the AQCR regime, these counties likely had lower pollution levels, but were designated as nonattainment because of the coarse resolution embodied in the AQCR regime. We interpret this as further evidence that nonattainment status under the AQCR regime had no discernible effect on manufacturing employment.

4.3 The Impact of Nonattainment Status on Manufacturing: Multi-Pollutant DiD Models

In section 4.2 we emphasized a note of caution when interpreting the parameter estimates in Table 7 since these models account for attainment status for only one pollutant. The concern is omitted variable bias: being in nonattainment for any one pollutant may capture the effects of being out of attainment with other pollutants. For example, 313 of the 433 counties out of attainment with TSP in 1978 were also out of attainment with at least one other pollutant. To control for such effects, we estimate models which specify three treatments: being out of attainment only for TSP; being out of attainment only for a pollutant other than TSP; and being out of attainment for both TSP and at least one other pollutant. The control groups consist of counties designated by EPA as in attainment with the NAAQS for all pollutants. Specifically, we estimate the model in (4), which includes county, year and either state-year or AQCR-year fixed effects:

$$\begin{aligned} y_{ct} =& \beta_1 Post_t \times (\text{NonAtt for TSP Only})_c + \beta_2 Post_t \times (\text{NonAtt for Other Only})_c \\ &+ \beta_3 Post_t \times (\text{NonAtt for TSP and Other})_c + \delta_c + \tau_t + \gamma_{st} + \epsilon_{ct}. \end{aligned} \tag{4}$$

Figure 4a and Figure 4b, which show trends in dirty manufacturing employment for the 1969-76 and 1975-88 periods for each of the four groups, foreshadow our econometric results. Summary statistics describing each group of counties for each time period appear in Table A8 of the Appendix. Figure 4a suggests no sign of dirty manufacturing employment declining as a result of the 1972 AQCR nonattainment status. There was a marked decline in dirty manufacturing employment from 1969 to 1971 and then an increase in dirty manufacturing employment until 1974. After a slight decrease during the 1974 recession, dirty manufacturing employment continued to rise.

Our econometric results, presented in Table 8, confirm our previous findings that 1972 AQCR nonattainment status did not reduce the ratio of dirty manufacturing to total employment.[9] Though column (1) displays a significant and negative coefficient for nonattainment only for TSP, the parallel trends assumption is not satisfied. Thus, even in the multi-pollutant models, there is no evidence of 1972 AQCR nonattainment reducing manufacturing employment among pollution-intensive industries in nonattainment relative to attainment counties in this period.

To see how 1972 nonattainment based on monitor readings affected employment we also estimate equation (4) using Greenstone's imputed designation of nonattainment. In this case, we report clear, causal evidence that nonattainment defined by county reduced employment in pollution intensive industries. In only one case, TSP in column (3), is the parallel trends assumption violated. The effect sizes are largest for nonattainment for multiple pollutants. These estimated effect sizes are largely in line with the results reported above.

Nonattainment status in 1978 also resulted in significant negative impacts on dirty manufacturing employment, as Figure 4b suggests. Dirty manufacturing employment was rising from 1975 through 1979 for all groups of counties. It began to decline thereafter, rising only slightly at the end of the 1982 recession. In light of these patterns, the results in columns (5) and (6) of Table 8 are not surprising. In accordance with our results in Tables 5 and 7, we do detect evidence of an adverse effect of nonattainment status on employment when using the county-based designations after 1978. Specifically, counties out of attainment in 1978 only for TSP, or for TSP and another pollutant, suffer a loss in employment relative to attainment counties. The coefficients for nonattainment only with pollutants other than TSP are not significant. As Table 8 shows, the estimated coefficients are not sensitive to whether we include state-year or AQCR-year fixed effects. Recall that our results in Tables 5 and 7 suggest nonattainment status for each pollutant exerted adverse effects on employment. However, when we simultaneously control for attainment status across all pollutants, it appears that TSP is the primary driver of job loss.

The coefficients in column (4) for being out of attainment only for TSP and being out of attainment for TSP and another pollutant yield an estimate of job losses of just under 295,000 from 1969 to 1976. The same coefficients in columns (5) and (6) imply a loss in employment of approximately 525,000 jobs from 1978 to 1988. Importantly, these estimates reflect average job losses over each period: 1969-76 and 1975-88. When combined over the 1969 to 1988 periods, our job loss estimates are considerably larger than Greenstone's estimated job losses of 592,000 over the period 1972-1987, Greenstone (2002). Further, our estimated job losses are associated

[9]The one exception to this, noted above, is the impact of 1972 nonattainment status for CO in the border-pair model.

with TSP nonattainment, rather than CO or Ozone as reported by Greenstone (2002).

5 Conclusion

In developed economies such as the U.S., a common role of government is the management of environmental externalities. The geographic scope of environmental externalities ranges from globally mixed pollutants like greenhouse gases to pollutants with localized impacts such as water pollutants and airborne particulate matter. These differences in physical dispersion and transport raise thorny questions regarding the appropriate geographic resolution of policy. One approach is to design policy so that compliance decisions reflect the full extent of pollution dispersion. An alternative policy design focuses on local effects, whereby compliance decisions are made at smaller spatial scales. The present paper sheds light on the importance of the geographic resolution of compliance determinations.

To explore these issues, we examine the U.S. CAA over the period from the late 1960s to the late 1980s. The CAA represents one of the most significant market interventions by the U.S. government in the post-World War II era (Greenstone 2004). Further, this period featured a substantive change, made in the 1977 amendments to the CAA, to the geographic resolution at which the CAA was implemented. Prior to 1977, compliance with the ambient air quality standards established by the CAA was determined for AQCRs, or multi-county airsheds (Murphy, 2017). After 1977, compliance designations were made on a county-by-county basis.

Our results clearly demonstrate that geographic design of environmental policies has significant implications for both environmental outcomes and the impact on regulated industries. Under the AQCR regime we find no evidence of differential air quality improvements or adverse employment effects for pollution-intensive industries in non-compliant AQCRs. In contrast, when compliance was determined by county, we report clear evidence of differential air quality improvements and job losses in nonattainment counties. However, prior to 1978, if nonattainment is defined in terms NAAQS exceedances using monitor readings, by county, we detect significant reductions in TSP and manufacturing employment in pollution-intensive industries, in accordance with the published literature (Greenstone 2002; Isen et al. 2017).

Based on these results, we believe that EPA determined that the AQCR, or airshed, was not an appropriate geographic resolution at which to regulate. We arrive at this conclusion for two reasons. First, our results suggest that regulatory pressure and resulting abatement activities were focused on the most polluted areas within the AQCRs, despite the fact that all counties within a state-AQCR pair were ascribed the same compliance designation. While it may have been rational for regulators to mitigate pollution in the most polluted areas, this approach resulted in a disconnect or misalignment between nonattainment designations and where abatement occurred.

Econometrically, the implication of the AQCR designation is that the treatment group (the nonattainment AQCRs) in fact contained numerous counties that did not exhibit pollution levels above the NAAQS. Accordingly, our models either fail to detect significant post-treatment differences in pollution and employment or the assumption of parallel pre-trends is violated because of the compositional complications posed by the AQCRs.

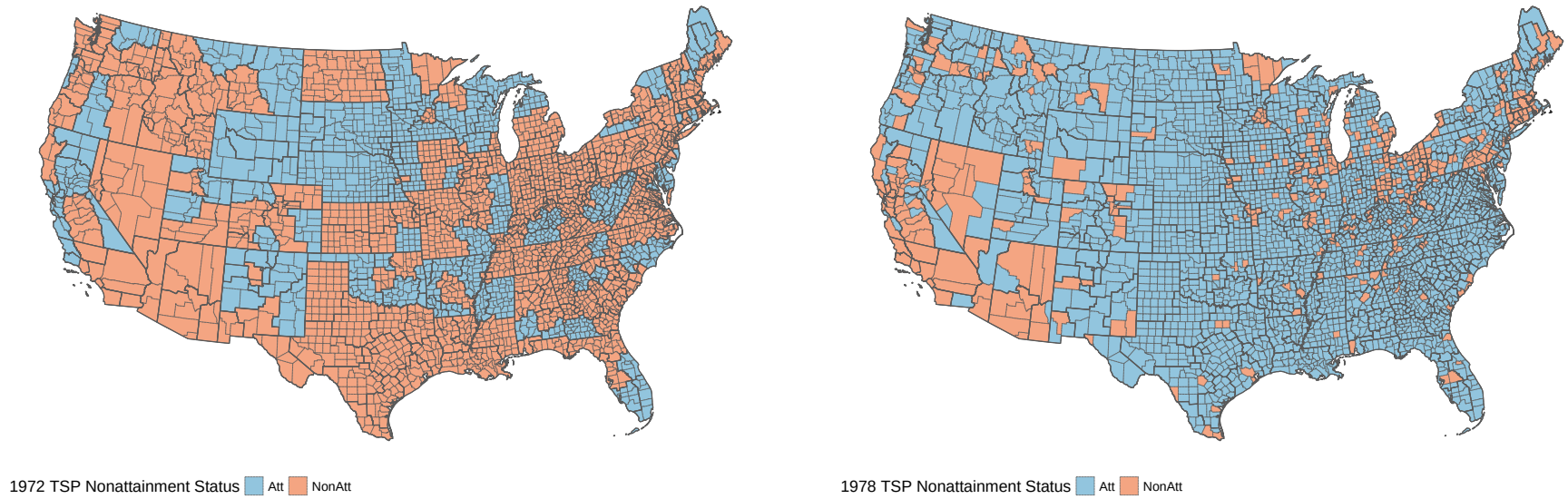
The net effect is to obscure the treatment effect of the CAA.

A second reason that we believe EPA determined the AQCRs were not a suitable geographic scale at which to levy compliance decisions relates to the management of new sources of pollution. Under the 1977 CAAA, new emitters (facilities) were deterred from entering nonattainment areas by requirements to install state-of-the-art pollution control equipment and to purchase emission offsets from existing sources. Further, because large swaths of the country were out of attainment with the NAAQS based on AQCR designations, these limits on firm entry would have curtailed growth. The transition to county-based attainment decisions reduced the number of nonattainment counties (see Table 1). This change in effect aligned efforts to mitigate pollution in nonattainment areas with elevated pollution readings, while not affecting growth in counties with pollution levels under the NAAQS

Our work has relevance to environmental policy design where questions about geographic scope and resolution are at issue. Designs that manage pollution according to flows in the natural environment have a strong and intuitive basis in the natural sciences. However, when regulations feature ambient standards, policymakers (and polluters) face incentives to prioritize abatement in highly polluted areas. If pollution is not well-mixed within the airshed or the watershed, coarsely defined compliance designations risk mischaracterizing geographic areas according to attainment or nonattainment status. The result, as our work shows, is to obscure policy effectiveness and to inefficiently manage society's joint goals of a clean environment and economic growth.

Figures and Tables

Figures

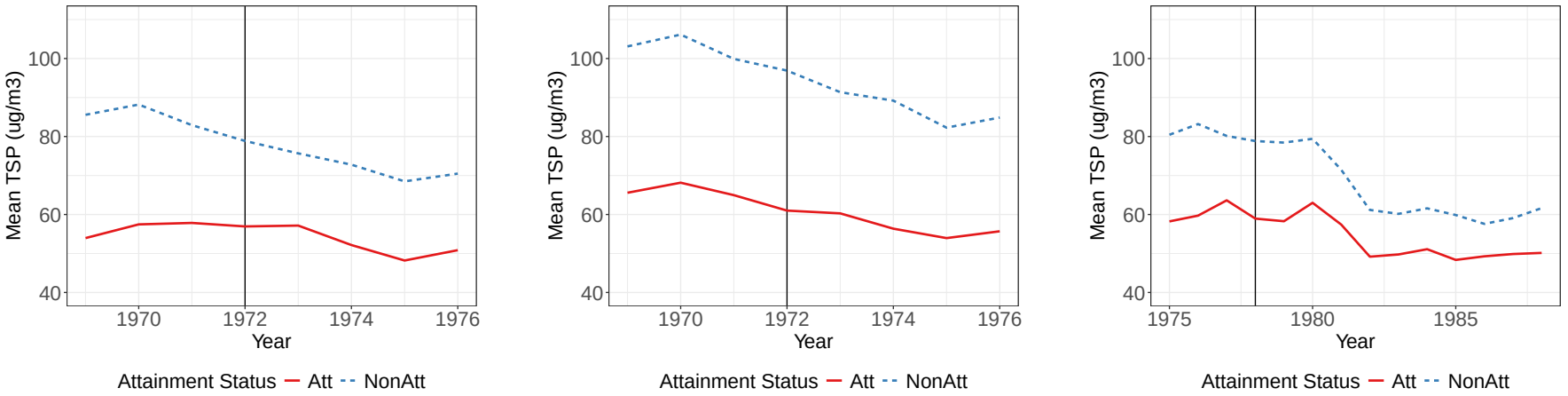


(a) EPA's Designation in 1972 by AQCR

(b) EPA's Designation in 1978 by County

Figure 1: Nonattainment Status for TSP in the Contiguous United States, 1972 and 1978

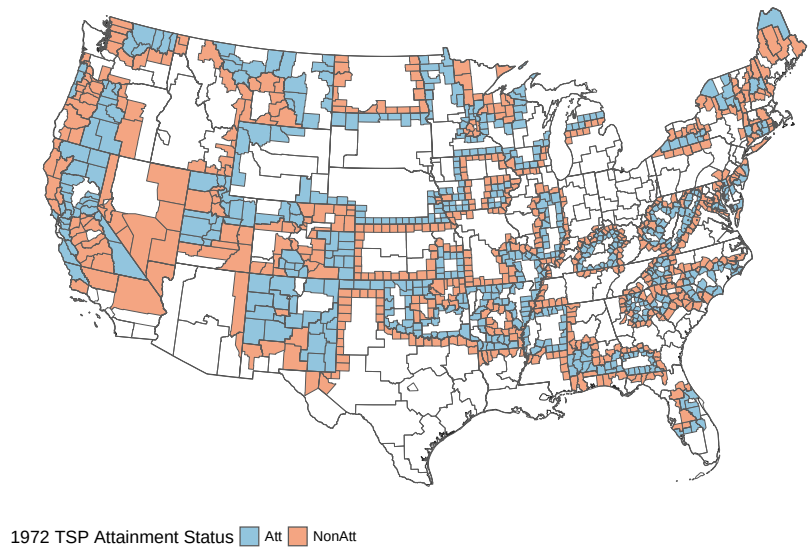
Note: This map shows the nonattainment status of counties in 1972 (left) and 1978 (right), based on EPA-designated attainment status in the contiguous United States.



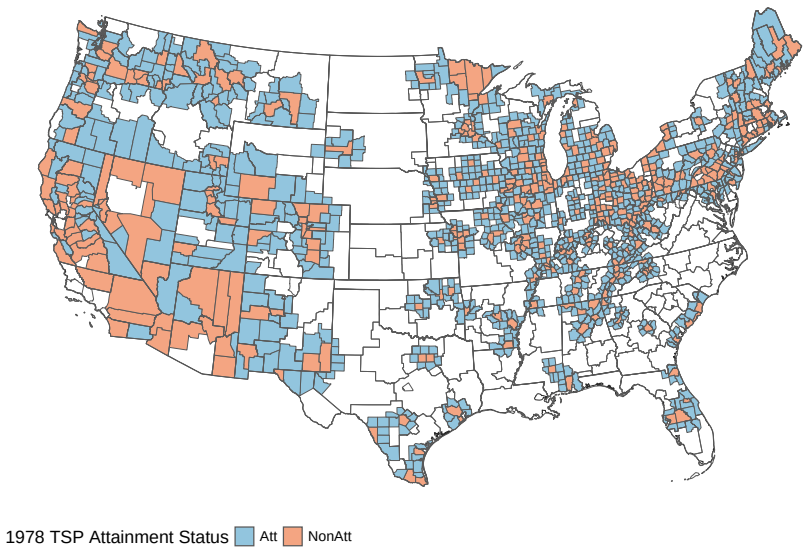
(a) EPA's Designation in 1972 by AQCR (b) Imputed Designation in 1972 by County (c) EPA's Designation in 1978 by County

Figure 2: Average TSP Levels by Attainment Status

Note: Panel (a) displays the average TSP levels for counties out of attainment and in attainment based on EPA-designated attainment status for TSP in 1972. Panel (b) presents the averages for counties based on the imputed nonattainment definition used in the literature (Greenstone 2020), which relies on monitor readings from 1971. Panel (c) shows the averages for counties based on EPA-designated attainment status for TSP in 1978. The number of counties included in these averages is provided in Table 2.



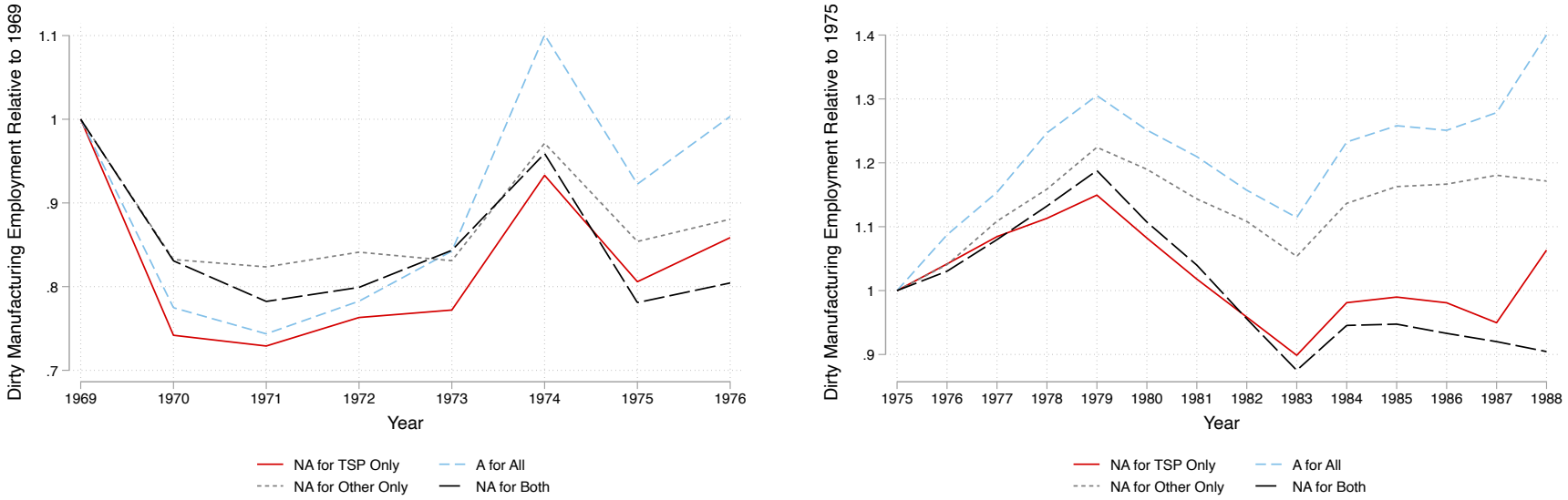
(a) EPA's Designation in 1972 by AQCR



(b) EPA's Designation in 1978 by County

Figure 3: Nonattainment Status for TSP in Counties Included in Border-pair Analysis, 1972 and 1978

Note: This map displays pairs of nonattainment and attainment counties sharing a border for TSP in 1972 (left) and 1978 (right), based on EPA-designated attainment status in the contiguous United States.



(a) EPA's Designation in 1972 by AQCR

(b) EPA's Designation in 1978 by County

Figure 4: Dirty Manufacturing Employment Trends by Attainment Status

Note: This figure shows trends in dirty manufacturing employment relative to 1969 for the period 1969-1976 (left) and relative to 1975 for the period 1975-1988 (right). In the figures, 'NA for TSP Only' refers to the average dirty manufacturing employment (relative to baseline) among counties out of attainment only for TSP, 'NA for Other Only' refers to counties out of attainment only for a non-TSP pollutant, 'NA for Both' refers to counties out of attainment for TSP and at least one other pollutant, and 'A for All' refers to counties in attainment for all four pollutants.

Tables

Table 1: Number of Nonattainment Counties in 1972 and 1978

Counties Out of Attainment for Individual Pollutants			
Pollutant	EPA's Designation in 1972 by AQCR	Imputed Designation in 1972 by County	EPA's Designation in 1978 by County
TSP	2069	296	433
CO	271	82	167
Ozone	651	32	685
SO_2	997	34	98
Breakdown by Nonattainment Status for TSP and Other Pollutants			
	Year		
Category	EPA's Designation in 1972 by AQCR	Imputed Designation in 1972 by County	EPA's Designation in 1978 by County
Out of attainment only for TSP	880	230	120
Out of attainment only for another pollutant	112	47	420
Out of attainment for TSP and at least one other pollutant	1189	66	313
In attainment for all four pollutants	932	2769	2259

Note: For column 2, we used the imputed designation from Greenstone (2020).

Table 2: Number of Counties with Balanced Monitors by TSP Attainment Status

	TSP Nonattainment Status Based on		
	EPA's Designation in 1972 by AQCR	Imputed Designation in 1972 by County	EPA's Designation in 1978 by County
Attainment	47	184	180
Nonattainment	262	125	222
Total	309	309	402

Note: This table shows the number of counties with balanced monitors—defined as counties with a balanced panel of TSP monitors operating in every year from 1969 and to 1976 (column 1 and 2) and from 1975 to 1988 (column 3). For column 2, we used the imputed designation from Greenstone (2020).

Table 3: Impact of Nonattainment on Mean Ambient TSP (1969-1988)

	EPA's Designation in 1972 by AQCR		Imputed Designation in 1972 by County			EPA's Designation in 1978 by County		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(Year $\geq$ 1972) $\times$ (NonAtt)	-8.946***	-6.272**	-5.358***	-6.259***	-5.674***			
	(1.638)	(2.526)	(1.897)	(1.986)	(2.130)			
(Year $\geq$ 1978) $\times$ (NonAtt)						-7.660***	-6.792***	-6.133***
						(1.211)	(1.293)	(1.504)
R^2	0.807	0.842	0.807	0.843	0.886	0.766	0.838	0.902
Observations	2,472	2,384	2,472	2,384	1,880	5,628	5,600	4,620
AQCR x Year FE					✓			✓
State x Year FE		✓		✓			✓	
Year FE	✓	✓	✓	✓	✓	✓	✓	✓
County FE	✓	✓	✓	✓	✓	✓	✓	✓
Pre-trend p-val	0.000	0.026	0.524	0.530	0.155	0.011	0.369	0.824

[a] * $p \leq 0.10$, ** $p \leq 0.05$, *** $p \leq 0.01$.
[b] Standard errors are clustered at the county level.
[c] Columns (1) through (4) are based on 1969-76 data, whereas columns (5) and (6) are based on 1975-88 data.
[d] "Pre-trend p-val" refers to the p-value for the null hypothesis that TSP-levels for treatment and control groups are the same in years prior to the designation. These years are 1969–1970 for columns (1)–(5) and 1975–1976 for columns (6)–(8).
[e] The dependent variable is the arithmetic average of TSP readings across all monitors in the county.
[f] For columns (3)-(5), we used the imputed designation from Greenstone (2020).

Table 4: Summary Statistics of Counties Used in Our Analysis, by TSP Nonattainment Status

(a) Year 1969-1976 (EPA's Designation in 1972 by AQCR)

	Counties Used in DiD Analysis				Counties Used in Border-Pairs			
	Nonattainment (N = 2066)		Attainment (N = 1044)		Nonattainment (N = 657)		Attainment (N = 1044)	
Variable	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Population (1,000s)	85.63	277.12	33.06	85.99	65.56	139.27	34.07	80.99
Employment (1,000s)	24.76	105.45	7.16	23.09	17.17	45.68	7.28	21.82
Dirty Manufacturing Employment (1,000s)	2.38	10.30	0.52	1.60	1.51	4.26	0.60	1.88
Ratio of Dirty to Total Employment	0.09	0.11	0.07	0.09	0.09	0.11	0.07	0.09

(b) Year 1975-1988 (EPA's Designation in 1978 by County)

	Counties Used in DiD Analysis				Counties Used in Border-Pairs			
	Nonattainment (N = 433)		Attainment (N = 2679)		Nonattainment (N = 393)		Attainment (N = 950)	
Variable	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Population (1,000s)	290.84	573.31	38.75	83.94	251.24	417.98	50.60	100.24
Employment (1,000s)	106.99	246.91	10.19	27.48	92.09	194.92	13.46	35.10
Dirty Manufacturing Employment (1,000s)	7.92	16.47	0.75	1.60	6.90	12.27	1.03	2.06
Ratio of Dirty to Total Employment	0.10	0.08	0.08	0.09	0.10	0.08	0.09	0.09

[a] Attainment group in the DiD analysis consists of the counties that are in attainment for TSP.
[b] Population information is missing for some counties. Specifically, in the upper table, 35, 18, 4, and 3 counties were excluded for each of the four columns, respectively. In the lower table, 12, 0, 0, and 6 counties were excluded.
[c] The statistics are calculated for the years 1969–1976 in the upper table, and for the years 1975–1988 in the lower table.

Table 5: Impact of Nonattainment on Dirty Manufacturing Employment Ratio (1969-1988): Border-Pair Approach

	EPA's Designation in 1972 by AQCR				EPA's Designation in 1978 by County			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Pollutants	TSP	CO	Ozone	SO_2	TSP	CO	Ozone	SO_2
(Year $\geq$ 1972) $\times$ (NonAtt)	-0.004	-0.007**	-0.004	0.000				
	(0.002)	(0.003)	(0.003)	(0.003)				
(Year $\geq$ 1978) $\times$ (NonAtt)					-0.009***	-0.008***	-0.004**	-0.014***
					(0.002)	(0.002)	(0.002)	(0.004)
R^2	0.905	0.909	0.907	0.915	0.951	0.959	0.947	0.940
Observations	20,876	8,093	14,469	15,254	42,775	17,051	31,144	13,104
N. of Border-Pairs?	1,308	509	908	957	1,535	613	1,118	468
CountyPair X Year FE	✓	✓	✓	✓	✓	✓	✓	✓
County FE	✓	✓	✓	✓	✓	✓	✓	✓
Pre-trend p-val	0.006	0.379	0.256	0.382	0.172	0.089	0.352	0.307

[a] * $p \leq 0.10$, ** $p \leq 0.05$, *** $p \leq 0.01$.

[b] Standard errors are clustered at the county level.

[c] Columns (1) through (4) are based on 1969-76 data, whereas columns (5) and (8) are based on 1975-88 data.

[d] "Pre-trend p-val" refers to the p-value for the null hypothesis that dirty manufacturing employment ratio for treatment and control groups are the same in years prior to the designation. These years are 1969–1970 for columns (1)–(4) and 1975–1976 for columns (5)–(8).

Table 6: Impact of TSP Nonattainment on Dirty Manufacturing Employment Ratio (1969-1976): Border-Pair Approach

	EPA's Designation in 1972 by AQCR	Imputed Designation in 1972 by County	NAAQS (All Monitors)	NAAQS (Dirtiest Monitor)
	(1)	(2)	(3)	(4)
(Year $\geq$ 1972) $\times$ (NonAtt)	-0.004	-0.007***	-0.008***	-0.007***
	(0.002)	(0.002)	(0.002)	(0.002)
R^2	0.905	0.918	0.924	0.925
Observations	20,876	22,356	21,682	24,560
N. of Border Pairs?	1,308	1,405	1,361	1,544
N. Unique NonAtt Counties	657	287	290	343
CountyPair X Year FE	✓	✓	✓	✓
County FE	✓	✓	✓	✓
Pre-trend p-val?	0.006	0.126	0.676	0.616

[a] * $p \leq 0.10$, ** $p \leq 0.05$, *** $p \leq 0.01$.
[b] Standard errors are clustered at the county level.
[c] Panel A and B are based on 1969-76 data, whereas Panel C is based on 1975-88 data.
[d] "Pre-trend p-val" refers to the p-value for the null hypothesis that dirty manufacturing employment ratio for treatment and control groups are the same in years 1969–1970 (prior to the designation).

Table 7: Impact of Nonattainment on Dirty Manufacturing Employment Ratio (1969-1988): Single Pollutant DiD Approach

	TSP		CO		Ozone		SO_2	
Panel A: EPA's Designation in 1972 by AQCR								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(NonAtt)× (Year ≥ 1972)	-0.006**	0.011	-0.004	0.012	-0.005**	0.014	0.001	0.012
	(0.002)	(0.013)	(0.003)	(0.011)	(0.002)	(0.012)	(0.003)	(0.009)
Observations	24809	24752	24809	24752	24809	24752	24809	24752
R-sq	0.817	0.832	0.817	0.832	0.817	0.832	0.817	0.832
Pre-trend P-values	0.0137	0.7604	0.1486	0.1533	0.6598	0.3589	0.6490	0.6170
Panel B: Imputed Designation in 1972 by County								
	TSP		CO		Ozone		SO_2	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(NonAtt) × (Year ≥ 1972)	-0.007***	-0.006**	-0.007**	-0.005	-0.010***	-0.005	-0.015***	-0.011**
	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)	(0.005)
Observations	24801	24744	24801	24744	24801	24744	24801	24744
R-sq	0.817	0.832	0.817	0.832	0.817	0.832	0.817	0.832
Pre-trend P-values	0.0509	0.1557	0.7354	0.9530	0.2100	0.0108	0.7412	0.9148
Panel C: EPA's Designation in 1978 by County								
	TSP		CO		Ozone		SO_2	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(NonAtt) × (Year ≥ 1978)	-0.010***	-0.009***	-0.005***	-0.006***	-0.004**	-0.004	-0.016***	-0.014**
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.004)	(0.005)
Observations	43481	43369	43481	43369	43481	43369	43481	43369
R-sq	0.880	0.886	0.880	0.886	0.880	0.886	0.880	0.886
Pre-trend P-values	0.0468	0.1901	0.5368	0.2104	0.5731	0.3559	0.4369	0.5412
State × Year FEs	✓		✓		✓		✓	
AQCR × Year FEs		✓		✓		✓		✓

[a] Note: * $p \leq 0.10$, ** $p \leq 0.05$, *** $p \leq 0.01$.
[b] Standard errors are clustered at the county level.
[c] "Pre-trend p-val" refers to the p-value for the null hypothesis that dirty manufacturing employment ratio for treatment and control groups are the same in years prior to the designation. These years are 1969–1970 for Panel A and B and 1975–1976 for Panel C.
[d] All models include county and year fixed effects.

Table 8: Impact of Nonattainment on Dirty Manufacturing Employment Ratio (1969-1988): Multi-Pollutant DiD Approach

	EPA's Designation in 1972 by AQCR		Imputed Designation in 1972 by County		EPA's Designation in 1978 by County	
	(1)	(2)	(3)	(4)	(5)	(6)
(NonAtt for TSP Only) × (Year ≥ 1972)	-0.007**	-0.000	-0.005**	-0.005*		
	(0.003)	(0.016)	(0.002)	(0.003)		
(NonAtt for Other Only) × (Year ≥ 1972)	0.005	0.035	-0.007**	-0.008**		
	(0.005)	(0.023)	(0.004)	(0.004)		
(NonAtt for TSP and Other) × (Year ≥ 1972)	-0.003	0.022	-0.012***	-0.010***		
	(0.003)	(0.013)	(0.003)	(0.004)		
(NonAtt for TSP Only) × (Year ≥ 1978)					-0.010***	-0.009**
					(0.003)	(0.004)
(NonAtt for Other Only) × (Year ≥ 1978)					-0.004	-0.005
					(0.003)	(0.003)
(NonAtt for TSP and Other) × (Year ≥ 1978)					-0.011***	-0.011***
					(0.002)	(0.003)
Observations	24809	24752	24809	24752	43495	43383
R-squared	0.817	0.832	0.817	0.832	0.880	0.886
Pre-trend P-values						
(NonAtt for TSP Only) vs. (Att for All)	0.0255	0.8419	0.0656	0.1997	0.1910	0.2549
(NonAtt for Other Only) vs. (Att for All)	0.5921	0.0000	0.5559	0.7845	0.5762	0.3231
(NonAtt for TSP and Other) vs. (Att for All)	0.0235	0.5366	0.7292	0.3752	0.5723	0.7401
Total job loss				293,313	526,646	524,794
County FEs	✓	✓	✓	✓	✓	✓
Year FEs	✓	✓	✓	✓	✓	✓
State × Year FEs	✓		✓		✓	
AQCR × Year FEs		✓		✓		✓

[a] Note: * $p \leq 0.10$, ** $p \leq 0.05$, *** $p \leq 0.01$.
[b] Standard errors are clustered at the county level.
[c] Columns (1) through (4) are based on 1969-76 data, whereas columns (5) and (6) are based on 1975-88 data.
[d] "Pre-trend p-val" refers to the p-value for the null hypothesis that dirty manufacturing employment ratio for treatment and control groups are the same in years prior to the designation. These years are 1969–1970 for columns (1)–(2) and 1975–1976 for columns (3)–(4).

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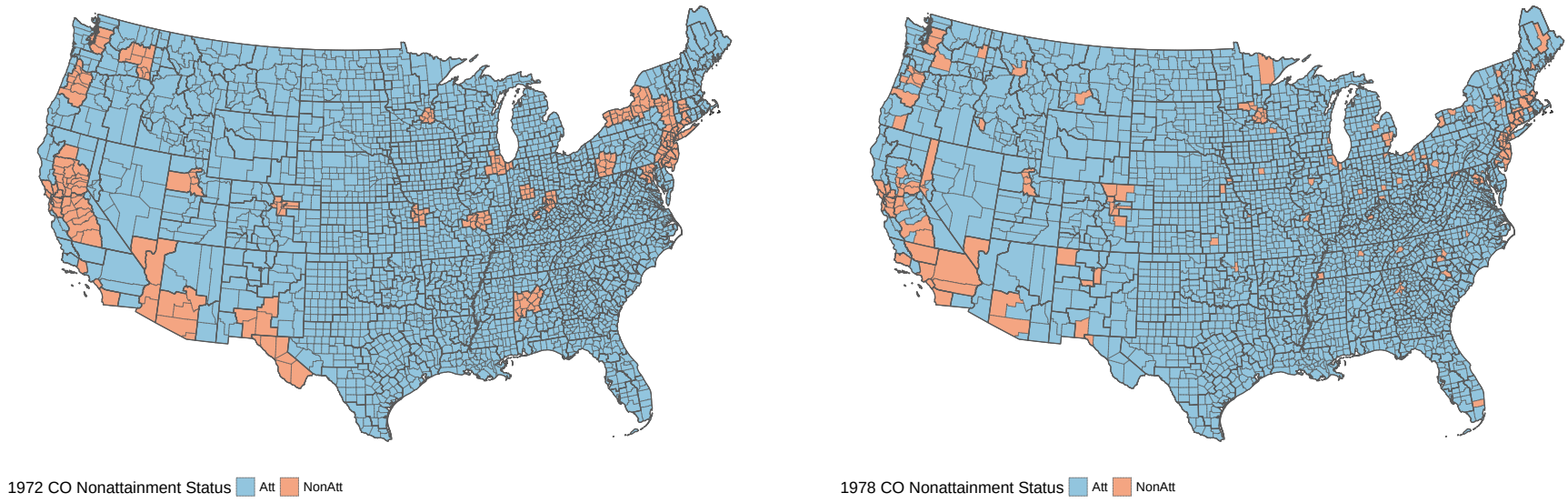
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Appendices

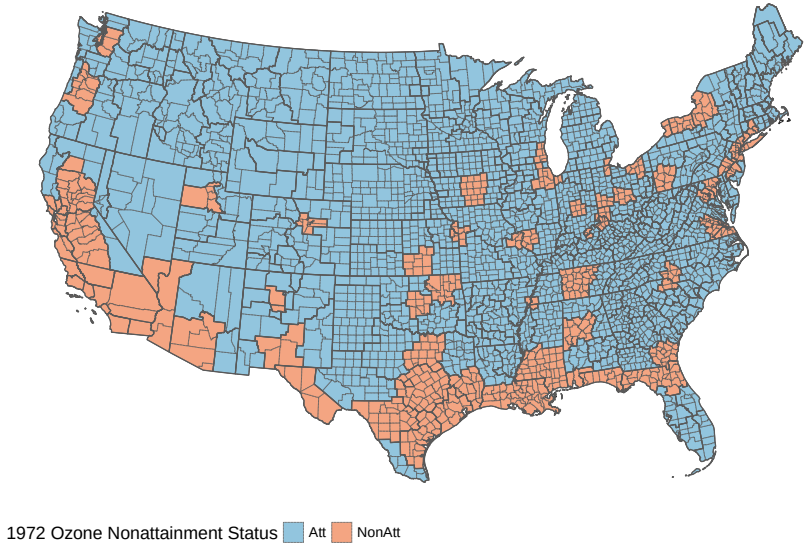


(a) EPA's Designation in 1972 by AQCR

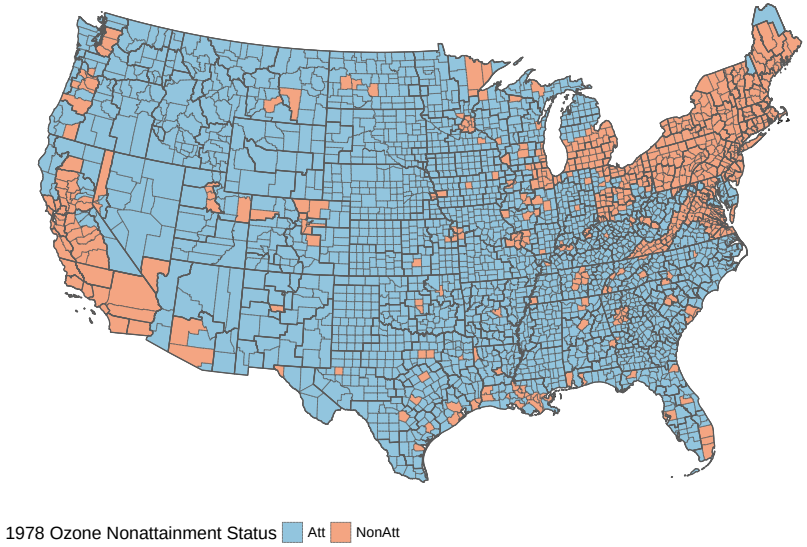
(b) EPA's Designation in 1978 by County

Figure A1: Nonattainment Status for CO in the Contiguous United States, 1972 and 1978

Note: This map shows the nonattainment status of counties in 1972 (left) and 1978 (right), based on EPA-designated attainment status in the contiguous United States.



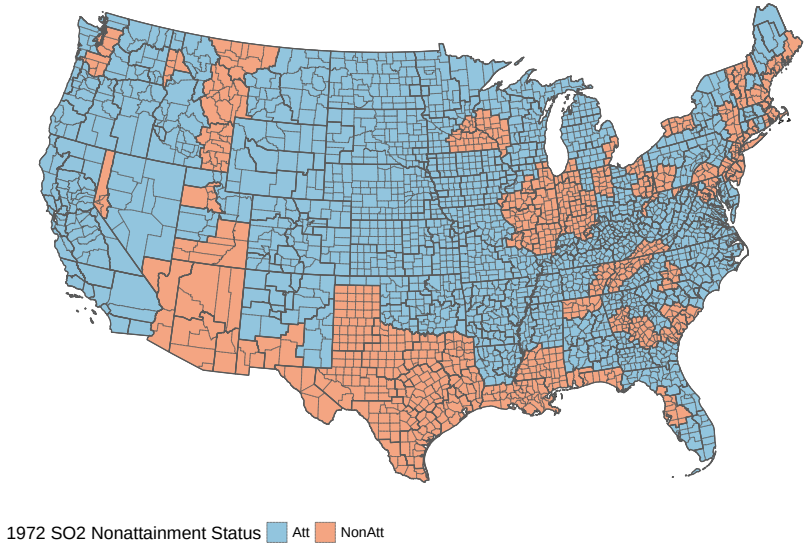
(a) EPA's Designation in 1972 by AQCR



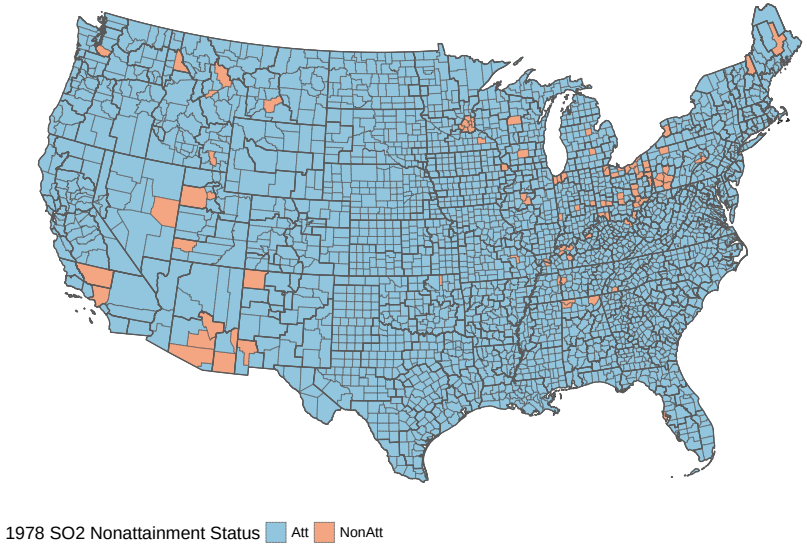
(b) EPA's Designation in 1978 by County

Figure A2: Nonattainment Status for Ozone in the Contiguous United States, 1972 and 1978

Note: This map shows the nonattainment status of counties in 1972 (left) and 1978 (right), based on EPA-designated attainment status in the contiguous United States.



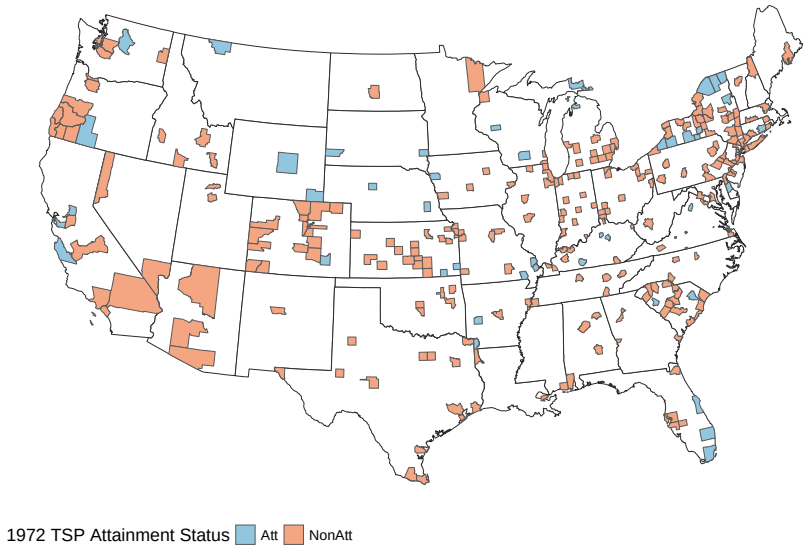
(a) EPA's Designation in 1972 by AQCR



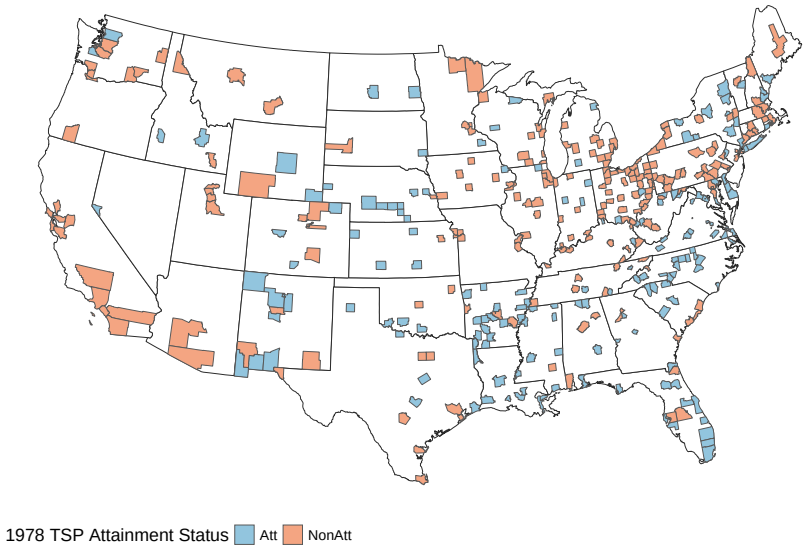
(b) EPA's Designation in 1978 by County

Figure A3: Nonattainment Status for SO_2 in the Contiguous United States, 1972 and 1978

Note: This map shows the nonattainment status of counties in 1972 (left) and 1978 (right), based on EPA-designated attainment status in the contiguous United States.



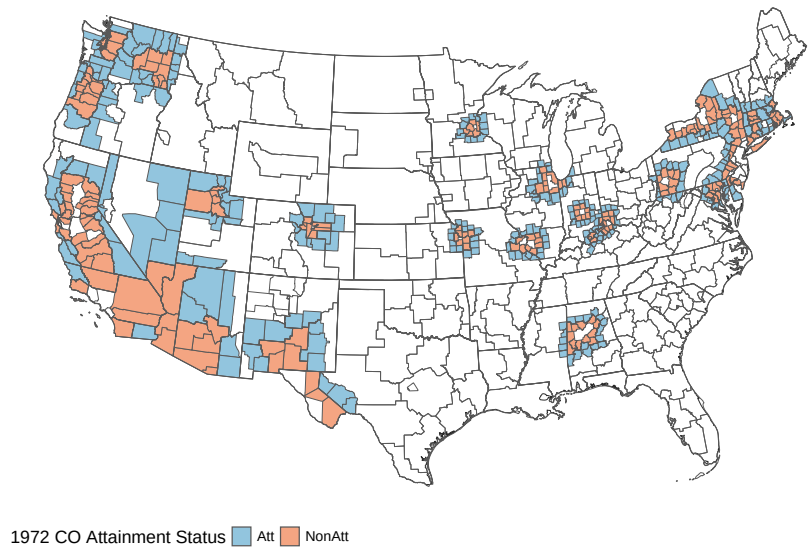
(a) EPA's Designation in 1972 by AQCR



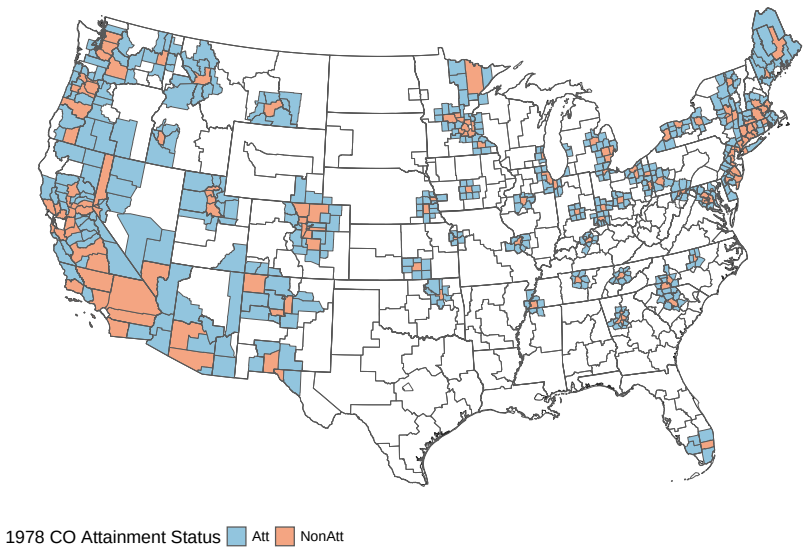
(b) EPA's Designation in 1978 by County

Figure A4: Counties With Balanced Monitors by TSP Nonattainment Status

Note: This map shows the nonattainment status of counties with balanced monitors—defined as counties with a balanced panel of TSP monitors operating in every year from 1969 and to 1976 (left) and from 1975 to 1988 (right).



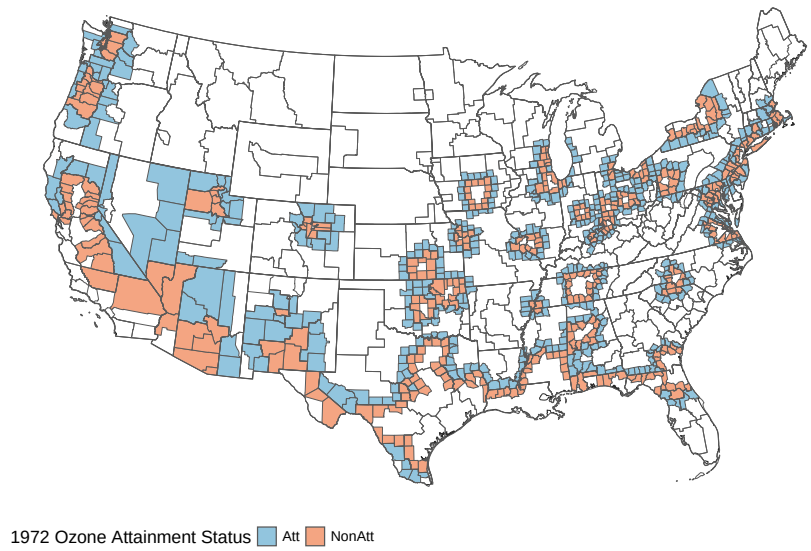
(a) EPA's Designation in 1972 by AQCR



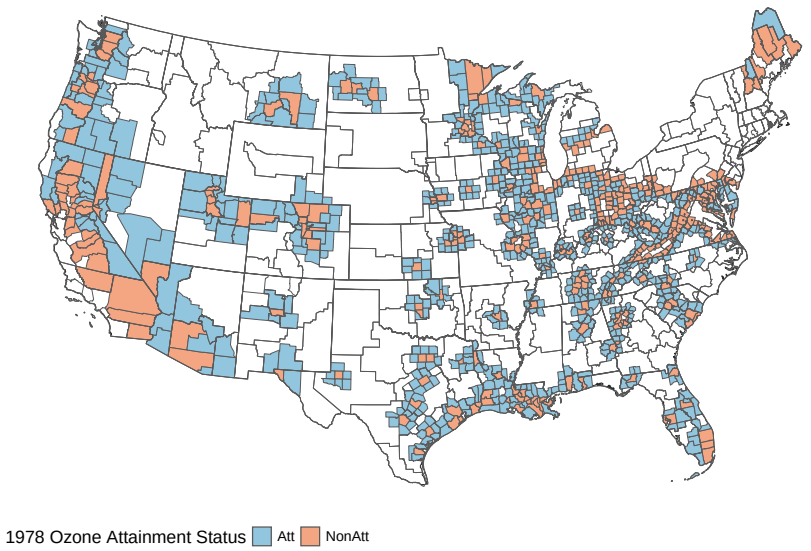
(b) EPA's Designation in 1978 by County

Figure A5: Nonattainment Status for CO in Counties Included in Border-Pair Analysis, 1972 and 1978

Note: This map displays pairs of nonattainment and attainment counties sharing a border for CO in 1972 (left) and 1978 (right), based on EPA-designated attainment status in the contiguous United States.



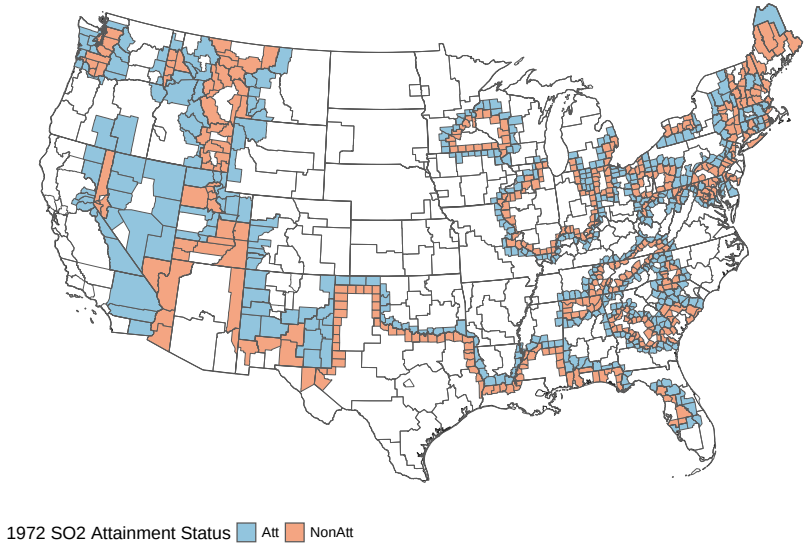
(a) EPA's Designation in 1972 by AQCR



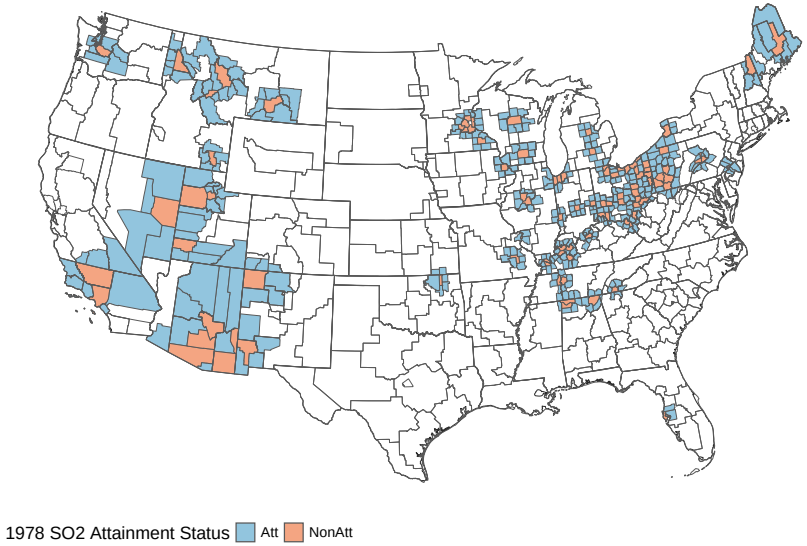
(b) EPA's Designation in 1978 by County

Figure A6: Nonattainment Status for Ozone in Counties Included in Border-Pair Analysis, 1972 and 1978

Note: This map displays pairs of nonattainment and attainment counties sharing a border for Ozone in 1972 (left) and 1978 (right), based on EPA-designated attainment status in the contiguous United States.



(a) EPA's Designation in 1972 by AQCR



(b) EPA's Designation in 1978 by County

Figure A7: Nonattainment Status for SO_2 in Counties Included in Border-Pair Analysis, 1972 and 1978

Note: This map displays pairs of nonattainment and attainment counties sharing a border for SO_2 in 1972 (left) and 1978 (right), based on EPA-designated attainment status in the contiguous United States.

Table A1: Summary Statistics by Attainment Status and Nonattainment Definition, Counties with Balanced Monitors

	Nonattainment Counties			Attainment Counties		
Variable	N	Mean	SD	N	Mean	SD
Panel A: Counties with Balanced Monitors 1969-76 (EPA's Designation in 1972 by AQCR)						
Population (1,000s)	257	356.71	649.90	47	164.04	271.38
Population density (people per square miles)	257	1.09	3.81	47	0.52	2.18
Employment (1,000s)	262	122.40	265.85	46	40.73	74.08
TSP readings from balanced monitors (ug/m3)	262	77.87	31.12	47	54.32	18.73
Panel B: Counties with Balanced Monitors 1969-76, (Imputed Designation in 1972 by County)						
Population (1,000s)	122	510.93	867.36	182	203.57	285.58
Population density (people per square miles)	122	1.74	5.36	182	0.50	1.36
Employment (1,000s)	125	185.19	359.96	183	58.72	93.84
TSP readings from balanced monitors (ug/m3)	125	94.22	32.77	184	60.75	20.14
Panel C: Counties with Balanced Monitors 1975-88 (EPA's Designation in 1978 by County)						
Population (1,000s)	222	426.64	742.00	173	160.75	240.17
Population density (people per square miles)	222	1.17	4.32	173	0.38	0.84
Employment (1,000s)	222	167.26	324.81	179	50.95	76.51
TSP readings from balanced monitors (ug/m3)	222	69.50	21.88	180	54.78	16.31

Note: Counties with balanced monitors are defined as counties with a balanced panel of TSP monitors operating in every year from 1969 and to 1976 (Panel A and B) and from 1975 to 1988 (Panel C). The statistics are calculated for the years 1969–1976 in Panels A and B, and for the years 1975–1988 in Panel C. For Panel B, we used the imputed designation from Greenstone (2020).

Table A2: Impact of Nonattainment on Mean Ambient TSP Under Alternative Nonattainment Designation Definitions

	Imputed Designation in 1972 by County			NAAQS (All Monitors) by County			NAAQS (Dirtiest Monitors) by County		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(Year $\geq$ 1972) $\times$ (NonAtt)	-5.358***	-6.259***	-5.674**	-8.621***	-9.145***	-7.593***	-9.267***	-8.743***	-7.650***
	(1.897)	(2.022)	(2.441)	(1.699)	(1.853)	(2.577)	(1.623)	(1.754)	(2.501)
R^2	0.807	0.853	0.926	0.809	0.855	0.926	0.810	0.855	0.927
Observations	2,472	2,384	1,880	2,472	2,384	1,880	2,472	2,384	1,880
AQCR x Year FE			✓			✓			✓
State x Year FE		✓			✓			✓	
Year FE	✓	✓	✓	✓	✓	✓	✓	✓	✓
County FE	✓	✓	✓	✓	✓	✓	✓	✓	✓
Pre-trend p-val	0.524	0.545	0.263	0.355	0.413	0.832	0.030	0.122	0.713

[a] Note: * $p \leq 0.10$, ** $p \leq 0.05$, *** $p \leq 0.01$.
[b] Standard errors are clustered at the county level.
[c] "Pre-trend p-val" refers to the p-value for the null hypothesis that TSP-levels for treatment and control groups are the same in years prior to the designation. These years are 1969–1970.
[d] The dependent variable is the arithmetic average of TSP readings across all monitors in the county.
[e] For columns (1)-(3) use the imputed nonattainment designation from Greenstone (2020). Columns (4)-(6) assign nonattainment status to counties where the geometric mean TSP level exceeds the NAAQS—either the annual average reading in 1971 exceeds 75 $\mu g/m^3$ or the second highest daily reading exceeds 260 $\mu g/m^3$). Columns (7)-(9) follow the same criteria as column (4)-(6), except nonattainment status is assigned based on the the monitor with the highest TSP reading in the county exceeding the NAAQS threshold.

Table A3: Polluting Manufacturing Industries

NAICS 2012	NAICS Descriptions	TSP	CO	Ozone	SO_2
313320	Fabric Coating Mills			1	
321113	Sawmills	1			
321114	Wood Preservation	1			
321211	Hardwood Veneer and Plywood Manufacturing	1			
321212	Softwood Veneer and Plywood Manufacturing	1			
321213	Engineered Wood Member (except Truss) Manufacturing	1			
321214	Truss Manufacturing	1			
321219	Reconstituted Wood Product Manufacturing	1			
321911	Wood Window and Door Manufacturing	1			
321912	Cut Stock, Resawing Lumber, and Planing	1			
321918	Other Millwork (including Flooring)	1			
321920	Wood Container and Pallet Manufacturing	1			
321991	Manufactured Home (Mobile Home) Manufacturing	1			
321992	Prefabricated Wood Building Manufacturing	1			
321999	All Other Miscellaneous Wood Product Manufacturing	1			
322110	Pulp Mills	1	1	1	1
322121	Paper (except Newsprint) Mills	1	1	1	1
322122	Newsprint Mills	1	1	1	1
322130	Paperboard Mills	1	1	1	1
323111	Commercial Printing (except Screen and Books)			1	
323113	Commercial Screen Printing			1	
323117	Books Printing			1	
324110	Petroleum Refineries		1	1	1
324199	All Other Petroleum and Coal Products Manufacturing	1	1	1	1
325110	Petrochemical Manufacturing			1	
325120	Industrial Gas Manufacturing			1	1
325193	Ethyl Alcohol Manufacturing			1	
325194	Cyclic Crude, Intermediate, and Gum and Wood Chemical Manufacturing			1	
325199	All Other Basic Organic Chemical Manufacturing			1	
325991	Custom Compounding of Purchased Resins			1	
326113	Unlaminated Plastics Film and Sheet (except Packaging) Manufacturing			1	
326121	Unlaminated Plastics Profile Shape Manufacturing			1	
326122	Plastics Pipe and Pipe Fitting Manufacturing			1	
326130	Laminated Plastics Plate, Sheet (except Packaging), and Shape Manufacturing			1	
326140	Polystyrene Foam Product Manufacturing			1	
326150	Urethane and Other Foam Product (except Polystyrene) Manufacturing			1	
326160	Plastics Bottle Manufacturing			1	
326191	Plastics Plumbing Fixture Manufacturing			1	
326199	All Other Plastics Product Manufacturing			1	
326211	Tire Manufacturing (except Retreading)			1	
326220	Rubber and Plastics Hoses and Belting Manufacturing			1	
326291	Rubber Product Manufacturing for Mechanical Use			1	
326299	All Other Rubber Product Manufacturing			1	
327110	Pottery, Ceramics, and Plumbing Fixture Manufacturing	1		1	1
327120	Clay Building Material and Refractories Manufacturing	1		1	1
327211	Flat Glass Manufacturing	1		1	1
327212	Other Pressed and Blown Glass and Glassware Manufacturing	1		1	1
327213	Glass Container Manufacturing	1		1	1
327215	Glass Product Manufacturing Made of Purchased Glass	1		1	1
327310	Cement Manufacturing	1		1	1
327320	Ready-Mix Concrete Manufacturing	1		1	1
327331	Concrete Block and Brick Manufacturing	1		1	1
327332	Concrete Pipe Manufacturing	1		1	1
327390	Other Concrete Product Manufacturing	1		1	1
327410	Lime Manufacturing	1		1	1
327420	Gypsum Product Manufacturing	1		1	1
327910	Abrasive Product Manufacturing	1		1	1
327991	Cut Stone and Stone Product Manufacturing	1		1	1
327992	Ground or Treated Mineral and Earth Manufacturing	1		1	1
327993	Mineral Wool Manufacturing	1		1	1
327999	All Other Miscellaneous Nonmetallic Mineral Product Manufacturing	1		1	1

331110	Iron and Steel Mills and Ferroalloy Manufacturing	1	1	1	1
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased Steel	1	1	1	1
331221	Rolled Steel Shape Manufacturing	1	1	1	1
331222	Steel Wire Drawing	1	1	1	1
331313	Alumina Refining and Primary Aluminum Production		1		1
331314	Secondary Smelting and Alloying of Aluminum		1		1
331410	Nonferrous Metal (except Aluminum) Smelting and Refining	1	1	1	1
331492	Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and Aluminum)		1		1
331511	Iron Foundries	1	1	1	1
331512	Steel Investment Foundries	1	1	1	1
331513	Steel Foundries (except Investment)	1	1	1	1
332111	Iron and Steel Forging			1	
332112	Nonferrous Forging			1	
332114	Custom Roll Forming			1	
332117	Powder Metallurgy Part Manufacturing			1	
332119	Metal Crown, Closure, and Other Metal Stamping (except Automotive)			1	
332215	Metal Kitchen Cookware, Utensil, Cutlery, and Flatware (except Precious) Manufacturing			1	
332311	Prefabricated Metal Building and Component Manufacturing			1	
332312	Fabricated Structural Metal Manufacturing			1	
332313	Plate Work Manufacturing			1	
332321	Metal Window and Door Manufacturing			1	
332322	Sheet Metal Work Manufacturing			1	
332323	Ornamental and Architectural Metal Work Manufacturing			1	
332410	Power Boiler and Heat Exchanger Manufacturing			1	
332420	Metal Tank (Heavy Gauge) Manufacturing			1	
332431	Metal Can Manufacturing			1	
332439	Other Metal Container Manufacturing			1	
332510	Hardware Manufacturing			1	
332613	Spring Manufacturing			1	
332618	Other Fabricated Wire Product Manufacturing			1	
332721	Precision Turned Product Manufacturing			1	
332722	Bolt, Nut, Screw, Rivet, and Washer Manufacturing			1	
332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacturers			1	
332911	Industrial Valve Manufacturing			1	
332912	Fluid Power Valve and Hose Fitting Manufacturing			1	
332913	Plumbing Fixture Fitting and Trim Manufacturing			1	
332919	Other Metal Valve and Pipe Fitting Manufacturing			1	
332992	Small Arms Ammunition Manufacturing			1	
332993	Ammunition (except Small Arms) Manufacturing			1	
332994	Small Arms, Ordnance, and Ordnance Accessories Manufacturing			1	
332996	Fabricated Pipe and Pipe Fitting Manufacturing			1	
332999	All Other Miscellaneous Fabricated Metal Product Manufacturing			1	
336111	Automobile Manufacturing			1	
336112	Light Truck and Utility Vehicle Manufacturing			1	
336120	Heavy Duty Truck Manufacturing			1	
336211	Motor Vehicle Body Manufacturing			1	
336212	Truck Trailer Manufacturing			1	
336213	Motor Home Manufacturing			1	
336310	Motor Vehicle Gasoline Engine and Engine Parts Manufacturing			1	
336330	Motor Vehicle Steering and Suspension Components (except Spring) Manufacturing			1	
336340	Motor Vehicle Brake System Manufacturing	1		1	1
336350	Motor Vehicle Transmission and Power Train Parts Manufacturing	1		1	1
336370	Motor Vehicle Metal Stamping			1	
336612	Boat Building			1	
336992	Military Armored Vehicle, Tank, and Tank Component Manufacturing			1	
337125	Household Furniture (except Wood and Metal) Manufacturing	1			
339920	Sporting and Athletic Goods Manufacturing			1	
339991	Gasket, Packing, and Sealing Device Manufacturing			1	
325130	Synthetic Dye and Pigment Manufacturing				1
325180	Other Basic Inorganic Chemical Manufacturing				1

Note: This table presents important polluters (classified by NAICS 2012) for each criteria pollutant. A "1" for a pollutant indicates that the industry is a polluter for that specific pollutant.

Table A4: Summary Statistics of Counties Used in Our Analysis, by CO Nonattainment Status

(a) Year 1969-1976 (EPA's Designation in 1972 by AQCR)

	Counties Used in DiD Analysis				Counties Used in Border-Pairs			
	Nonattainment (N = 271)		Attainment (N = 2839)		Nonattainment (N = 202)		Attainment (N = 284)	
Variable	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Population (1,000s)	321.86	644.84	43.47	111.24	221.51	458.80	61.22	114.76
Employment (1,000s)	100.82	255.96	11.08	38.11	63.63	174.54	15.78	38.14
Dirty Manufacturing Employment (1,000s)	8.44	21.86	1.12	5.39	5.94	18.71	1.69	4.03
Ratio of Dirty to Total Employment	0.09	0.09	0.08	0.10	0.10	0.09	0.10	0.11

(b) Year 1975-1988 (EPA's Designation in 1978 by County)

	Counties Used in DiD Analysis				Counties Used in Border-Pairs			
	Nonattainment (N = 167)		Attainment (N = 2945)		Nonattainment (N = 149)		Attainment (N = 458)	
Variable	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Population (1,000s)	577.10	814.54	45.52	101.14	536.57	826.57	85.18	143.25
Employment (1,000s)	220.39	352.24	12.50	38.49	202.86	338.65	22.28	42.61
Dirty Manufacturing Employment (1,000s)	13.63	23.72	1.07	2.89	13.47	24.79	2.17	4.53
Ratio of Dirty to Total Employment	0.07	0.05	0.09	0.09	0.07	0.05	0.09	0.08

[a] Attainment group in the DiD analysis consists of the counties that are in attainment for CO.
[b] Population information is missing for some counties. Specifically, in the upper table, 18, 0, 0, and 0 counties were excluded for each of the four columns, respectively. In the lower table, 12, 1, 1, and 2 counties were excluded.
[c] The statistics are calculated for the years 1969–1976 in the upper table, and for the years 1975–1988 in the lower table.

Table A5: Summary Statistics of Counties Used in Our Analysis, by Ozone Nonattainment Status

(a) Year 1969-1976 (EPA's Designation in 1972 by AQCR)

	Counties Used in DiD Analysis				Counties Used in Border-Pairs			
	Nonattainment (N = 648)		Attainment (N = 2462)		Nonattainment (N = 377)		Attainment (N = 500)	
Variable	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Population (1,000s)	180.20	461.49	38.83	93.35	140.50	346.33	56.05	146.75
Employment (1,000s)	54.12	178.02	9.58	30.07	38.75	129.91	14.35	49.38
Dirty Manufacturing Employment (1,000s)	4.66	15.60	0.99	4.94	3.98	14.34	1.83	9.46
Ratio of Dirty to Total Employment	0.10	0.10	0.08	0.10	0.10	0.11	0.10	0.10

(b) Year 1975-1988 (EPA's Designation in 1978 by County)

	Counties Used in DiD Analysis				Counties Used in Border-Pairs			
	Nonattainment (N = 685)		Attainment (N = 2427)		Nonattainment (N = 341)		Attainment (N = 725)	
Variable	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Population (1,000s)	249.93	493.59	27.95	37.61	208.41	291.88	37.01	37.74
Employment (1,000s)	83.31	203.46	6.81	12.67	68.63	120.53	8.49	11.69
Dirty Manufacturing Employment (1,000s)	5.88	13.53	0.58	1.07	4.57	7.17	0.80	1.30
Ratio of Dirty to Total Employment	0.10	0.08	0.08	0.09	0.10	0.08	0.10	0.09

[a] Attainment group in the DiD analysis consists of the counties that are in attainment for Ozone.
[b] Population information is missing for some counties. Specifically, in the upper table, 16, 18, 7, and 0 counties were excluded for each of the four columns, respectively. In the lower table, 12, 45, 14, and 1 counties were excluded.
[c] The statistics are calculated for the years 1969–1976 in the upper table, and for the years 1975–1988 in the lower table.

Table A6: Summary Statistics of Counties Used in Our Analysis, by SO_2 Nonattainment Status

(a) Year 1969-1976 (EPA's Designation in 1972 by AQCR)

	Counties Used in DiD Analysis				Counties Used in Border-Pairs			
	Nonattainment (N = 995)		Attainment (N = 2115)		Nonattainment (N = 434)		Attainment (N = 482)	
Variable	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Population (1,000s)	108.27	299.63	48.86	189.89	97.42	211.84	51.40	106.64
Employment (1,000s)	32.56	122.30	12.39	63.69	27.51	72.77	13.26	35.66
Dirty Manufacturing Employment (1,000s)	3.08	12.56	1.13	5.53	3.15	11.50	1.58	4.84
Ratio of Dirty to Total Employment	0.09	0.10	0.08	0.10	0.10	0.11	0.10	0.11

(b) Year 1975-1988 (EPA's Designation in 1978 by County)

	Counties Used in DiD Analysis				Counties Used in Border-Pairs			
	Nonattainment (N = 98)		Attainment (N = 3014)		Nonattainment (N = 97)		Attainment (N = 355)	
Variable	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Population (1,000s)	313.22	829.63	66.51	193.67	311.63	833.75	95.96	332.46
Employment (1,000s)	117.47	336.62	20.55	81.04	116.31	338.15	29.68	136.43
Dirty Manufacturing Employment (1,000s)	10.03	22.65	1.48	5.33	9.99	22.77	2.50	9.65
Ratio of Dirty to Total Employment	0.13	0.10	0.08	0.08	0.13	0.10	0.11	0.09

[a] Attainment group in the DiD analysis consists of the counties that are in attainment for SO_2.
[b] Population information is missing for some counties. Specifically, in the upper table, 10, 18, 1, and 4 counties were excluded for each of the four columns, respectively. In the lower table, 12, 0, 1, and 0 counties were excluded.
[c] The statistics are calculated for the years 1969–1976 in the upper table, and for the years 1975–1988 in the lower table.

Table A7: Impact of Nonattainment on Mean Ambient TSP and Dirty Manufacturing Employment Ratio: Combined 1972 and 1978 Designations

	y = Mean Ambient TSP		y = Dirty Manufacturing Employment Ratio							
	TSP		TSP		CO		Ozone		SO_2	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(Year $\geq$ 1978) $\times$ (NN)	-8.306**	-7.561***	-0.015***	-0.009	-0.004	0.001	-0.006***	0.002	-0.021***	-0.010
	(3.224)	(2.338)	(0.002)	(0.006)	(0.003)	(0.007)	(0.002)	(0.007)	(0.006)	(0.011)
(Year $\geq$ 1978) $\times$ (NA)	-0.276	0.567	-0.005***	0.002	-0.001	0.007	-0.002	0.008	0.002	0.010
	(2.632)	(1.775)	(0.002)	(0.006)	(0.003)	(0.008)	(0.002)	(0.007)	(0.002)	(0.007)
(Year $\geq$ 1978) $\times$ (AN)	-3.100	-2.717	-0.002	-0.000	-0.008***	-0.007***	-0.003	-0.002	-0.007	-0.006
	(5.031)	(4.328)	(0.004)	(0.004)	(0.002)	(0.002)	(0.002)	(0.003)	(0.005)	(0.006)
R^2	0.794	0.800	0.880	0.886	0.880	0.886	0.880	0.886	0.880	0.886
Observations	5,390	5,600	43,481	43,369	43,481	43,369	43,481	43,369	43,481	43,369
Pre-trend p-val:										
NN vs. AA	0.6724	0.4781	0.0108	0.0046	0.9790	0.9085	0.4188	0.8364	0.9263	0.0000
NA vs. AA	0.5872	0.5404	0.0134	0.8439	0.2960	0.2931	0.0976	0.3986	0.7818	0.0869
AN vs. AA	0.5047	0.6817	0.0438	0.0626	0.5210	0.2985	0.9825	0.4621	0.2964	0.6029
AQCR x Year FE				✓		✓		✓		✓
State x Year FE	✓	✓	✓		✓		✓		✓	
County FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

[a] This table examines the impact of nonattainment status in 1972 and 1978 for the pollutants listed in the table on two outcomes. Columns (1) and (2) model the impact of NA status for TSP on ambient TSP; columns (3)-(10) examine the impact of TSP, CO, Ozone and SO_2 on the ratio of dirty manufacturing to total employment.
[b] 'NN' refers to counties designated as nonattainment for the pollutant (shown in the column headings) under both the 1972 AQCR regime and the 1978 county-based designations. 'NA' refers to counties in nonattainment only under the AQCR regime, while 'AN' refers to those in nonattainment only under the 1978 county-based regime. 'AA' indicates to those counties in attainment under both regimes.
[c] Note: * $p \leq 0.10$, ** $p \leq 0.05$, *** $p \leq 0.01$.
[d] Standard errors are clustered at the county level.
[e] "Pre-trend p-val" refers to the p-value for the null hypothesis that the dirty manufacturing employment ratio was the same between the treatment groups (NN, NA, and AN, respectively) and the control group (AA) prior to the 1978 designation (1975–1976).

Table A8: Summary Statistics of Counties Used in Multi-Pollutant DiD Models

(a) Year 1969-1976 (EPA's Designation in 1972 by AQCR)

	TSP Only (N = 880)		Other Only (N = 112)		TSP and Other (N = 1189)		Control Group (N = 932)	
Variable	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Population (1,000s)	39.74	77.84	86.15	183.34	119.87	356.13	26.54	61.53
Employment (1,000s)	10.21	25.66	21.70	60.09	35.54	136.40	5.41	11.59
Dirty Manufacturing Employment (1,000s)	1.15	3.59	1.45	4.04	3.29	13.17	0.41	0.89
Ratio of Dirty to Total Employment	0.09	0.11	0.07	0.09	0.09	0.10	0.06	0.09

(b) Year 1969-1976 (Imputed Designation in 1972 by County)

	TSP Only (N = 230)		Other Only (N = 47)		TSP and Other (N = 66)		Control Group (N = 2769)	
Variable	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Population (1,000s)	170.78	322.33	507.49	439.78	687.48	1079.43	36.95	79.33
Employment (1,000s)	48.33	100.25	163.34	154.66	261.56	458.01	8.15	20.18
Dirty Manufacturing Employment (1,000s)	5.44	15.78	11.64	11.77	22.68	40.26	0.78	2.29
Ratio of Dirty to Total Employment	0.10	0.10	0.08	0.06	0.10	0.08	0.08	0.10

(c) Year 1975-1988 (EPA's Designation in 1978 by County)

	TSP Only (N = 120)		Other Only (N = 419)		TSP and Other (N = 313)		Control Group (N = 2258)	
Variable	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Population (1,000s)	54.33	54.30	116.64	187.06	380.70	650.50	25.78	34.87
Employment (1,000s)	14.94	16.54	32.04	59.10	141.96	282.12	6.15	11.96
Dirty Manufacturing Employment (1,000s)	1.52	1.95	2.06	3.09	10.36	18.75	0.51	0.94
Ratio of Dirty to Total Employment	0.11	0.10	0.10	0.09	0.10	0.07	0.08	0.08

[a] Attainment group in the DiD analysis consists of the counties that are in attainment for all four pollutants.
[b] Population information is missing for some counties. Specifically, in table (a), 13, 0, 22, and 18 counties were excluded for each of the four columns, respectively. In table (b), 9, 0, 0, and 44 counties were excluded. In table (c), 0, 45, 0, and 12 counties were excluded.
[c] The statistics are calculated for the years 1969–1976 in the upper table, and for the years 1975–1988 in the lower table.