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THE CLEAN AIR ACT OF 1970 AND ADULT MORTALITY*

K. Chay, C. Dobkin, M. Greenstone

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ABSTRACT

Previous research has established an association between air pollution and adult mortality. However, studies utilizing short-term fluctuations in pollution may detect mortality changes among the already ill or dying, while prospective cohort studies, which utilize geographic differences in long-run pollution levels, may suffer from severe omitted variables bias. This study utilizes the long-run reduction in total suspended particulates (TSPs) pollution induced by the Clean Air Act of 1970, which mandated aggressive regulation of local polluters in heavily polluted counties. We find that regulatory status is associated with large reductions in TSPs pollution but has little association with reductions in either adult or elderly mortality. These findings are interpreted with caution due to several caveats.

Keywords: Particulates Pollution, Clean Air Act, Adult and Elderly Mortality

JEL classification: I12, I18, Q25

Previous epidemiologic research has established an association between air pollution and excess mortality among adults. These studies have used either time-series or cross-sectional research designs. Time series studies typically utilize abrupt fluctuations in pollution levels in an area or areas, while cross-sectional studies utilize long-term differences in pollution levels across cities, counties or other geographical units. These two approaches have different strengths and weaknesses.

Several time series designs have convincingly documented an association between a short term elevation in air pollution levels and increased morbidity and mortality. In studies examining historical episodes, there is a clear relationship between very large spikes in pollution, such as the London Fog of 1952, and elevated mortality. Time-series analyses of more recent periods are based on daily fluctuations in air pollution that are considerably smaller. These studies estimate the regression-adjusted correlation between hospital admissions or deaths and pollution levels from the preceding days for a single city or area. They find that temporary increases in pollution are associated with increases in adult mortality (see Dockery and Pope (1996)).

Two problems arise in interpreting these findings. First, short-term variation in pollution is often not anthropogenic. For example, sharp changes in particulate levels are often driven by local weather conditions rather than by changes in the pollution generating activity.[1] Since weather conditions may also serve to concentrate other pollutants and irritants, it is unclear which pollutant caused the adverse health effects. A second, more serious issue is that time-series designs can only identify the acute effects of pollution. Thus, it is possible that temporarily elevated pollution levels may hasten the mortality of adults who were already very ill and likely to die within days or weeks anyways. In this case, the actual loss of life expectancy associated with elevated pollution levels may be much smaller than these studies implicitly suggest.

Cross-sectional studies, on the other hand, follow prospective cohorts in areas with long-term differences in air pollution (e.g., Dockery, et al. (1993)). As a result, they can, in principle, accurately estimate the loss of life expectancy associated with elevated pollution levels. However, this design may

[1] Many locations, including several large urban areas such as the LA basin, are prone to weather inversions. The reduction in the vertical mixing of the air during inversions results in the decreased dispersal of locally generated pollutants.

face more severe omitted variables problems than time series designs. In particular, the cities, counties, or zip codes that are compared may be different in important ways other than just in their levels of air pollution. If so, the resulting estimate of the effect of pollution on adult mortality may be an artifact of influences other than air pollution.

Table 1 provides information on the demographics of and per-capita transfer payments to counties based on their 1971 total suspended particulates (TSPs) concentrations. High TSPs counties have higher per-capita Income Maintenance Benefits, Family Assistance, Food Stamps and Public Assistance Medical Care transfers. They also have a higher percentage of black residents. Thus, counties with high and low TSPs levels exhibit significant differences in characteristics that are likely to be associated with shortened life expectancies (e.g., socioeconomic status of the county population). This suggests that the cross-sectional association between pollution and early mortality may not be causal.

This paper implements an alternate research design that avoids some of the pitfalls associated with the two research design discussed above. In particular, we utilize the annual change in particulates pollution induced by the Clean Air Act Amendments (CAAA) of 1970. The CAAA designated counties with annual, average TSPs concentrations exceeding a federally-determined threshold as nonattainment. Polluters in these counties faced stricter regulations than polluters in the attainment counties that comprise the remainder of the country.

We compare the changes in TSPs and mortality across nonattainment and attainment counties in the first year that the CAAA was in force. By focusing on annual changes in TSPs and mortality rates, the design will not detect the small changes in life expectancy (e.g., changes of a week or month) that may underlie the associations in time series studies. Further, the division of the country into attainment and nonattainment counties was based on pollution levels, not expected changes in mortality rates. We demonstrate that attainment and nonattainment counties, especially near the federal threshold, have similar characteristics the year before the legislation took effect. Thus, this design has the potential to reduce the role of omitted variables bias.

We find that in the first year after the implementation of the CAAA, TSPs concentrations declined significantly more in nonattainment counties than in attainment ones. However, there is little systematic association between nonattainment status and changes in adult and elderly mortality rates. The results imply that the regulation-induced reduction in TSPs is not associated with improvements in adult or elderly mortality. Although this design is likely to reduce the misspecification associated with time series and cross-sectional regressions, we find differences between nonattainment and attainment counties in their pre-regulation mortality rates and trends that may undermine the design's validity.

1. Research Design

The ideal way to assess the impact of TSPs on human health would be to run a randomized trial. Since such an experiment is unethical, we rely on variation in county-level changes in TSPs induced by the 1970 CAAA.

The centerpiece of the 1970 CAAA was the establishment of separate federal standards, known as the National Ambient Air Quality Standards (NAAQS), for six pollutants. The CAAA's goal was to reduce local air pollution concentrations so that all U.S. counties were in compliance with the NAAQS by 1975 (with the possibility of an extension to 1977). The first step toward achieving this goal was the assignment of pollutant-specific 'attainment-nonattainment' designations in 1972 for all U.S. counties for each of the regulated pollutants. If pollution concentrations in a county exceeded the federal ceiling, then the EPA was required to designate the county as nonattainment for that pollutant. For TSPs, the nonattainment designation was reserved for counties with TSPs concentrations that exceeded either of two thresholds: 1) the annual geometric mean concentration exceeded 75 micrograms-per-cubic meter ($\mu g/m^3$), or 2) the second highest daily concentration exceeded 260 $\mu g/m^3$.[2] The CAAA imposed substantially stricter regulations on polluters in nonattainment counties (than in attainment ones).[3] This study exploits this variation in regulation intensity by using nonattainment status as an instrumental variable for 1971-1972 changes in TSPs in equations for 1971-1972 changes in adult mortality rates.

[2] This standard prevailed from 1971 until 1987, when the EPA shifted its focus to the regulation of finer particles.
[3] Despite extensive efforts, we were unable to obtain a list of the counties that were initially designated TSPs nonattainment by the EPA. Consequently, we assign counties with TSPs concentrations exceeding the NAAQS in 1970 to the 1972 TSPs nonattainment category. All other counties with nonmissing TSPs data are designated attainment for that year. See Chay and Greenstone (2003b) for more details on the CAAA and the determination of the nonattainment designation.

This attainment-nonattainment based research design may avoid some of the pitfalls of the time series and cross-sectional approaches to estimating the human health-TSPs relationship. First, by focusing on annual changes in TSPs and mortality rates, the design will not detect the small changes in life expectancy that may underlie the findings of time series studies. For example, if reduced levels of TSPs delay mortality for individuals by only 1 month, our approach will only detect the reduction in mortality that would have occurred in December but now occurs in January. Further, our approach will detect changes in mortality associated with longer gains in life expectancy. These types of health benefits could justify the costly abatement activities imposed on polluters.

Second, this design may reduce the omitted variables problems that exist in the cross-sectional approach. TSPs nonattainment status is associated with sharp variation in changes in TSPs across counties in the early 1970s. Further, nonattainment status in 1972 is a discrete function of the annual geometric mean and second highest daily concentrations of TSPs in the regulation selection year, 1970. Thus, the assignment of regulatory status has the feature of a quasi-experimental regression-discontinuity design (Cook and Campbell (1979)). If other factors affecting infant mortality are similar for counties just above and just below the regulatory threshold, then comparing outcome changes in nonattainment and attainment counties with pre-regulation TSPs levels just around the threshold will control for all omitted factors correlated with TSPs.

2. Data

To implement our design we use the most comprehensive county-level data available on population, mortality, TSPs and economic conditions for the 1969-1974 period. Here, we describe the data sources, their limitations, and present some summary statistics.

The county population estimates for 1969 come from the National Cancer Institute SEER database. The county population estimates for 1970-1974 come from the U.S. Census Bureau. The files provide populations by county and year. Within each county, the populations are divided into cells of five-year age blocks by gender and race. Race has three categories -- black, white and other. The populations are directly calculated in the Census year, 1970, and are adjusted based on the numbers of births and deaths and estimated migration patterns in the non-Census years.[4]

The county-level mortality data come from the National Center for Health Statistics (NCHS) Mortality Detail files. These files contain a census of all deaths occurring in the United States and provide the age, race, gender, cause of death, and county of residence of the decedent.[5] We collapse the micro data into county, race, gender and age cells to match the population estimates. Due to significant differences in how the Census and NCHS code "Other Race", we combined "Other Race" and Black.

The annual monitor-level data on TSPs concentrations were obtained by filing a Freedom of Information Act request with the EPA. This yielded annual summary information from the EPA's nationwide network of pollution monitors, including the location of each monitor and their readings. The data also contain information on the annual geometric mean TSPs concentration for each monitor in a county and the number of daily monitor readings exceeding the federal standards in each year. From these data, we calculated the mean TSPs concentrations in each county and year. These measures are also used to determine the annual nonattainment status of each county.

We also collected information on county-level economic conditions. The Bureau of Economic Analysis' annual series provides per-capita income, per-capita earnings, proportion of adult population employed, and proportion of adults employed in manufacturing for each county. From the Regional Economic Information System file, we obtained annual county-level per-capita transfer payments, expenditures on medical care for low income individuals and family assistance payments.[6]

The last column of Table 1 presents a summary of the data elements from the five data sources for the subset of counties with TSPs data in 1970, 1971, and 1972. These 501 counties form the base sample used in our analysis. The second row shows that although we have TSPs data for only 1/6th of the more than 3,000 counties in the U.S., these counties account for more than 60% of the population over 50 years old in the U.S. The next rows present the racial, gender and age compositions of the counties

[4] A description of the methods used is available at http://eire.census.gov/popest/topics/methodology/casrh_doc.txt.
[5] For 1972 only, a 50% random sample of all death certificates was collected. All other years provide the census of death certificates.
[6] Detailed descriptions of these data are provided in Chay and Greenstone (2003b).

included in the study, as well as the mean TSPs concentrations. The next rows present the employment, per-capita transfer payments, expenditures on medical care for low income individuals, and family assistance payments. All means are weighted by the county populations.

The final rows present the yearly mortality rates for adults aged over 50 by five-year age blocks. The one-year death rate of adults over 80 years old is ten times the death rate of adults in their fifties. This has two implications for our analysis. First, small differences in the age structure of a county or group of counties can result in significant differences in mortality rates. In our analysis, we control for the population proportions in each 5-year age category, but mismeasurement of these variables could induce bias in our estimates. For example, the migration models used by the Census may fail to capture systematic migration to or from high pollution concentration counties. Second, we separately examine the effect of TSPs on adults over the age of 50 and those between the ages of 65 and 84. The former group should be less selected on nonrandom mortality differences than the latter group. However, due to their higher death rates, the latter group may be more sensitive to changes in air quality. In addition, this group has been the focus of several economic and epidemiologic studies (e.g., Fuchs, McClellan, and Skinner (2001)).

3. Econometric Methods

Our analysis compares changes in adult mortality rates and TSPs pollution from 1971-1972 for counties that were nonattainment and attainment for TSPs in 1972. Here, we discuss the econometric models used to estimate the adult mortality-TSPs association. For simplicity, it is assumed that the "true" effect of exposure to particulates pollution is homogeneous across adults and over time.

The cross-sectional model predominantly used in the literature on pollution and health is:

(1) $y_{ct} = X_{ct}'\beta + \theta T_{ct} + \varepsilon_{ct}, \qquad \varepsilon_{ct} = \alpha_c + u_{ct}$

(2) $T_{ct} = X_{ct}'\Pi + \eta_{ct}, \qquad \eta_{ct} = \lambda_c + v_{ct},$

where y_{ct} is the adult mortality rate in county c in year t, X_{ct} is a vector of observed characteristics, T_{ct} is the mean of TSPs across all monitors in the county, and ε_{ct} and η_{ct} are the unobservable determinants of adult mortality rates and TSPs levels, respectively. The coefficient θ is the 'true' effect of TSPs on adult mortality. For consistent estimation, the least squares estimator of θ requires $E[\varepsilon_{ct}\eta_{ct}]=0$. If there are omitted permanent (α_c and λ_c) or transitory (u_{ct} and v_{ct}) factors that covary with both TSPs and adult mortality, then the cross-sectional estimator will be biased.

With repeated observations over time, a "fixed-effects" model implies that first-differencing the data will absorb the permanent county effects, α_c and λ_c. This leads to:

(3) $y_{ct} - y_{ct-1} = (X_{ct} - X_{ct-1})'\beta + \theta(T_{ct} - T_{ct-1}) + (u_{ct} - u_{ct-1})$

(4) $T_{ct} - T_{ct-1} = (X_{ct} - X_{ct-1})'\Pi + (v_{ct} - v_{ct-1})$.

For identification, the fixed effects estimator of θ requires $E[(u_{ct} - u_{ct-1})(v_{ct} - v_{ct-1})]=0$. That is, there are no unobserved shocks to TSPs levels that covary with unobserved shocks to adult mortality rates. Although first-differencing removes permanent county factors as a source of bias, it likely magnifies the importance of misspecification due to measurement error in the population's exposure to TSPs. Such mismeasurement will attenuate the estimated TSPs coefficient, and the degree of attenuation is positively related to the fraction of the total variation in observed TSPs that is due to mismeasurement.

Now, suppose there exists an instrumental variable, Z_c, that causes changes in TSPs without having a direct effect on adult mortality rate changes. Such a variable would purge the estimates of the bias associated with the covariance between unobserved shocks to TSPs levels and unobserved shocks to adult mortality rates and the bias due to measurement error. One plausible instrument is the CAAA regulatory intervention for TSPs, measured by the 1972 attainment-nonattainment status of a county.[7] Here, equation (4) becomes:

(5) $T_{c72} - T_{c71} = (X_{c72} - X_{c71})'\Pi_{TX} + Z_{c72}\Pi_{TZ} + (v_{c72} - v_{c71})$, and

(6) $Z_{c72} = 1(T_{c70} > \bar{T}) = 1(v_{c70} > \bar{T} - X_{c70}'\Pi - \lambda_c)$,

where Z_{c72} is the regulatory status of county c in 1972, $1(\bullet)$ is an indicator function equal to one if the enclosed statement is true, and $\bar{T}$ is the maximum concentration of TSPs allowed by the federal regulations. Regulatory status in 1972 is a discrete function of 1970 pollution levels.[8]

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[7] See Chay and Greenstone (2003b) for details on the timing of the CAAA intervention.

[8] We have written (6) as if regulatory status is a function of a single threshold crossing. Only six counties were nonattainment in 1972 for exceeding the 2nd highest daily concentration threshold, but not the annual geometric mean ceiling.

An attractive feature of this research design is that the reduced-form relations between 1972 TSPs nonattainment status and the two endogenous variables provide direct measures of the benefits of the regulations. In particular, Π_{TZ} from equation (5) measures the change in TSPs concentrations in nonattainment counties relative to attainment ones. In the other reduced-form equation,

(7) $$y_{c72} - y_{c71} = (X_{c72} - X_{c71})'\Pi_{yX} + Z_{c72}\Pi_{yZ} + (u_{c72} - u_{c71}),$$

Π_{yZ} captures the relative change in adult mortality rates. Since the instrumental variables (IV) estimator (θ_{IV}) of the effect of TSPs on the adult mortality rate is exactly identified, it is a simple function of the two reduced-form relations -- that is, $\theta_{IV} = \Pi_{yZ}/\Pi_{TZ}$.

Two sufficient conditions for θ_{IV} to provide a consistent estimate of the effect of TSPs are $\Pi_{TZ} \neq 0$ and $E[v_{c70}(u_{c72} - u_{c71})] = 0$. The first condition requires that the regulations induced air quality improvements. The second condition requires that unobserved mortality rate shocks from 1971-72 are orthogonal to transitory shocks to 1970 TSPs levels.

Even if $E[v_{c70}(u_{c72} - u_{c71})] \neq 0$, causal inferences on θ may be possible by leveraging the regression discontinuity (RD) design implicit in the $1(\bullet)$ function that determines nonattainment status. For example, if $E[v_{c70}(u_{c72} - u_{c71})] = 0$ in the neighborhood of the regulatory ceiling (i.e., 75 $\mu g/m^3$), then a comparison of changes in nonattainment and attainment counties in this neighborhood will control for all omitted variables. The analysis below presents estimates of θ_{IV} based on all counties and RD estimates when the sample is limited to counties with TSPs concentrations "near" the 75 $\mu g/m^3$ threshold in the regulation selection year.

4. Results

4.1 Cross Section Results

Table 2 presents our replication of the cross-sectional approach to estimating the association between pollution and adult mortality that is common in the literature. For adults aged over 50 (top rows) and the elderly aged 65-84 (bottom rows), we run separate regressions for each year from 1969-1974 with four different sets of covariates. In all cases, the dependent variable is the number of deaths per 10,000 residents. Column 1 presents the unadjusted association between mortality and TSPs. Column 2 presents results based on regressions that include dummies for race, gender and age, while column 3 adds county-level measures of employment, income, medical expenditures and income assistance as controls. The final column adds state fixed effects to the specification. The heteroskedastic consistent standard errors are presented below the point estimate in parentheses, and the sample sizes and R-squareds are presented in brackets below the standard errors.

The estimated associations between mean TSPs levels and mortality rates vary widely, both across specifications for a given year and across years for a given specification. Consistent with the findings of previous studies, the unadjusted correlations in column 1 are always positive, though often not statistically significant. Both the point estimates and standard errors shrink as additional covariates are included in the regressions. The shrinking of the standard errors is expected and reflects the greatly improved fit of the regressions. The dramatic shrinking of the point estimates between the first and fourth columns is due to systematic differences in the observable characteristics of more and less polluted counties. This finding was foreshadowed by the first four columns of Table 1.

Of the 24 regression estimates for adults over the age of 50, three show a significant positive association between TSPs and mortality, two show a significant negative association, and the remaining estimates are insignificant at conventional levels. Not surprisingly, the estimates for the elderly are larger in magnitude but are similarly variable. Overall, these results are not consistent with the view that higher TSPs pollution levels are significantly associated with excess adult mortality.

4.2 Fixed Effects Results

Table 3 presents the fixed effects estimates of the association between TSPs pollution and deaths among adults over the age of 50 (first four columns) and deaths among the elderly (last four columns). The top panel shows the results from models that include county fixed effects in regressions based on the pooled data from 1969-1974. The bottom panel shows the results based on 1971-1972 first differences of the data. Similar to Table 2, column 1 shows the unadjusted estimate and columns 2-4 progressively add more controls.

The results do not support the hypothesis of a relationship between changes in TSPs and changes in adult mortality. For the over-50 age category, two of the eight parameter estimates would be judged statistically significant by conventional criteria, but one of these has a negative sign while the other has a positive sign. In fact, 7 of the 8 estimates are "perversely" signed (i.e., they indicate that increases in TSPs decrease adult mortality). The results for the 65-84 age category are similar.

4.3 Instrumental Variables Results

We begin with Table 4, which examines whether the nonattainment instrumental variable is orthogonal to the observable predictors of adult mortality. While not a formal test of the exogeneity of the instrument, it seems reasonable to presume that research designs that meet this criteria may suffer from smaller omitted variables bias. First, designs that balance the observable covariates may be more likely to also balance the unobservables. Second, if the instrument balances the observables, then consistent inference does not depend on functional form assumptions on the relations between the observable confounders and adult mortality. Estimators that misspecify these functional forms (e.g., linear regression adjustment when the conditional expectations function is nonlinear) will be biased.

The first column reports the 1971 means of the characteristics in the 231 counties that were attainment in 1972. The second column does the same for the 270 counties that were nonattainment in 1972.[9] Column 3 presents the t-statistics for the differences between columns 1 and 2. It is evident that there are significant differences in many of the covariates in the year before regulation. Columns 4-6 and 7-9 repeat this analysis for the subsets of counties with TSPs in the regulation selection year (i.e., 1970) between 45 and 105 $\mu g/m^3$ and 60 and 90 $\mu g/m^3$, respectively. In the 45-105 $\mu g/m^3$ group, there are still large differences in many of the variables between the two sets of counties. However, the observables are much better balanced in the 60-90 $\mu g/m^3$ group of counties, with only 5 of the variables showing statistically significant differences between the two sets counties. This suggests that the most reliable results may come from this subsample of nonattainment and attainment counties.

[9] The 6 counties that are nonattainment due to the "bad day" rule only are included in the nonattainment group.

Figure 1 presents the time series of mean TSPs levels from 1969 to 1974 for the three different samples of attainment and nonattainment counties in Table 4.[10] Panel A shows mean TSPs levels for each group of counties, and panel B plots the differences in mean TSPs between nonattainment and attainment counties within each sample of counties. For the sample of all counties, there is a sharp decline in pollution levels among the nonattainment counties after 1971. In contrast, there is only a modest decline in TSPs levels in attainment counties in the years after the CAAA was in force. Panel B further demonstrates that there were substantial relative reductions in TSPs in nonattainment counties even when the sample is restricted to counties with regulation selection year concentrations between 45 and 105 $\mu g/m^3$ and 60 and 90 $\mu g/m^3$. Overall, these graphs document a strong "first-stage" relationship between nonattainment status and reductions in ambient TSPs concentrations after 1971.

Figure 2, which is structured identically to Figure 1, graphically presents the reduced-form relationship between nonattainment status and mortality rates for adults over the age of 50. The average one-year death rate in this period is 314 deaths per 10,000 residents. It is evident that 1972 TSPs nonattainment status is not associated with an improvement in adult mortality rates from 1971 to 1972. The plots also reveal that nonattainment counties had significantly lower mortality in the period before the regulations were in force, 1969-1971. Further, there is evidence of differential trends in mortality rates in the nonattainment and attainment counties leading up to 1971, with mortality rates falling more sharply in attainment counties. Although the observable covariates are more similar in the subgroup of counties near the regulatory threshold, paradoxically the pre-regulation mortality gap is even larger.[11]

Figure 3 repeats this analysis for adults aged 65-84. Here, the full and the 45-105 $\mu g/m^3$ samples show a greater reduction in mortality rates in nonattainment counties relative to attainment ones between 1971 and 1972. Notably, the 60-90 $\mu g/m^3$ sample exhibits a smaller mortality gap in the pre-regulation period (Panel B), but a 1971-1972 change in mortality rates that is roughly equal in nonattainment and attainment counties. The most striking patterns, however, are the differential pre-regulation trends in

[10] The samples are further restricted to the fixed set of counties with TSPs data in every year from 1969 to 1974. For Figures 1 to 3, county populations are used as weights.
[11] This is due to a combination of different age distributions and different mortality rates within a fixed aged category across the subsamples of counties (see Table 4).

nonattainment and attainment counties for all three samples. One potential interpretation of the plots is that the nonattainment designation caused the observed trend breaks in mortality differences after 1971 and thus substantially reduced adult mortality (relative to pre-existing trends). However, this seems speculative at best since the source of the pre-regulation trends is unknown. It seems more sensible to conclude that at least in this unadjusted setting, these pre-existing trends cast doubts on the validity of the research design. We return to this issue below.

Table 5 presents the results from estimating the reduced-form equations (5) and (7) for adults over the age of 50 (results for those aged 65-84 are available from the authors). The first five columns contain the estimated effects of 1972 nonattainment status on the 1971-1972 change in TSPs pollution, while the last five columns contain the association between nonattainment status and the 1971-1972 change in adult mortality. The first four columns are based on the same specifications as in Table 4. To address the differential demographic selection into attainment and nonattainment counties suggested by Figures 2 and 3, column 5 is based on a specification that allows the effects of age, gender, and race to be different in attainment and nonattainment counties. We discuss this approach below. Finally, each set of rows pertains to the three samples of counties – all counties, counties with 1970 TSPs between 45-105 $\mu g/m^3$, and counties with 1970 TSPs between 60-90 $\mu g/m^3$.

The results show that for all three sets of counties, 1972 nonattainment status is associated with a large and significant relative reduction in TSPs from 1971 to 1972. Although the point estimate changes little, the first-stage estimates from the specification that allows the effects of the controls to vary by nonattainment status (column 5) is statistically significant only for the sample of all counties. By contrast, there is little association between 1972 nonattainment status and reductions in adult mortality from 1971-1972. The column 5 specification, which attempts to control for differential selection into attainment and nonattainment counties, results in the largest estimated associations, but the point estimates are not significant at conventional levels. Thus, while the CAAA regulations led to dramatically improved air quality, they do not appear to have reduced adult mortality rates.

Table 6 presents the instrumental variables (IV) estimates of the effect of 1971-1972 changes in TSPs on both adult mortality rates (aged over 50) and elderly mortality rates (aged 65-84). The first panel contains the results for all the counties for which we have pollution data. The second and third panels report the IV estimates for the two RD subsamples of counties. The columns correspond to the same specifications used in Table 5 – thus, the IV estimates are equal to the ratio of the two sets of reduced-form estimates in Table 5.

The IV results confirm the impression from the graphical analysis in Figures 2 and 3. For adult mortality over the age of 50, none of the 15 estimates of the effect of TSPs is statistically significant at conventional levels. Further, 10 of the 15 estimates have a "perverse" negative sign. The estimates for the elderly are more systematically positive (13 out of 15 estimates), but none are significant at conventional levels. Also, the smallest point estimates are for the 60-90 $\mu g/m^3$ subsample, in which the observables and mortality rates of attainment and nonattainment counties in the pre-regulation period are the most similar. The IV estimates are positive and largest in the final column, but they are not significant and based on statistically weak first-stage relations for the two RD subsamples. Overall, these results are not consistent with the hypothesis that annual changes in TSPs are associated with changes in adult or elderly mortality.

5. Discussion of Caveats

We interpret the above findings with caution due to several, potentially significant problems with our research design.[12] It should be noted that these problems also plague the cross-sectional approaches common to the literature. Further, cross-sectional designs have the additional problem of not allowing for a careful evaluation of the quality of the comparisons that underlie the estimates – a key issue given the strong association between socioeconomic status and pollution exposure shown in Table 1.

For the comparison of the attainment and nonattainment counties to be valid, the observable characteristics and the mortality rates of the residents in the two groups should be similar in the years preceding the intervention. This is not the case. The first two columns of Table 4 revealed that attainment and nonattainment counties are systematically different in 1971. A particular issue is the large

[12] The research design used in this study does appear to be valid for examining the infant mortality effects of TSPs pollution. That is, all of the problems discussed here are mitigated in the context of infants. See Chay and Greenstone (2003b) for details.

difference in the age distributions of the counties since age is highly correlated with mortality. Figures 2B and 3B showed that attainment and nonattainment counties also have different mortality rates and different mortality trends in the period before the large reduction in pollution in 1972.

We implemented two approaches to address this. First, we focused on the set of counties with 1970 TSPs levels near the regulatory threshold. Columns 4 through 9 of Table 4 showed that focusing on these counties reduces the difference in the observable characteristics. However, even in the most restricted subsample, there are still some statistically significant differences between nonattainment and attainment counties. Further, this approach did little to reduce the differences in mortality levels and trends in the pre-regulation period. For example, Figure 3B showed that while focusing on the subsample of counties near the regulatory threshold significantly reduces the mortality rate differences for 65-84 year olds, it does not completely eliminate the differential pre-regulation trends in mortality. Figure 2B showed that focusing on these counties actually results in greater differences in mortality rates for those over 50 years old between nonattainment and attainment counties.

Our second approach was to correct for the observable differences between counties in a regression context. When examining regression-adjusted mortality rates in figures similar to Figures 2 and 3, this approach greatly reduced the differences in mortality levels in the years before regulation (results available from the authors). However, significant differences still remained, particularly in the pre-regulation trends. The fact that adjusting for observable characteristics did not balance the mortality trends suggests that our analysis is still biased by omitted variables. For example, instead of knowing the exact age of residents, we only observe the proportions in five-year age categories. This could be problematic if there are significant differences in the health endowments of 75 and 79 year olds. Further, due to differential selection of adults and elderly into attainment and nonattainment counties, it is possible that health endowments may differ even among people of exactly the same age.

To address this potential for differential selection on unobservable health endowments, we estimated a model that allowed the effects of the demographic variables (age, race, and gender) to have different loading factors for attainment and nonattainment counties (column 5 of Table 6). This model did significantly reduce the differences in mortality rate trends in the pre-regulation period. However, as shown in Table 5, interacting the control variables with the instrument also greatly increases the noise in the first-stage association between nonattainment status and TSPs changes. Further, this approach admits that the nonattainment indicator is not fully exogenous conditional on the observables. Nonetheless, the resulting estimates of the effect of TSPs on adult mortality were large and positive, though not significant at conventional levels.

There are three other issues that affect the interpretation of our results. First, the population estimates for 1971 and 1972 are based on Census projections rather than actual enumerations of the number of residents. Any error in these projections due to unpredictable migration patterns, for example, will lead to biased estimates. Second, the lifetime exposure of adults to air pollution is unknown. Studies of adult health effects implicitly assume that the current pollution concentration observed at a site accurately measures each resident's lifetime exposure. While our study utilizes pollution changes, there may be differences in the cumulative lifetime exposures of adults in nonattainment and attainment counties that bias our findings.

Finally, it has been hypothesized that fine and ultrafine particles, such as PM-10 or PM-2.5, are more likely to penetrate deeply into the lungs and produce inflammatory responses than large particles. Due to its biological plausibility, many recent studies have focused on the effects of PM-10. Our study, on the other hand, examines total suspended particulates, which includes PM-10 but also includes larger particles.[13] Thus, it is not informative about whether small particles have more severe health effects than large particles. However, since the CAAA regulations were focused on industrial and fuel-combustion related emissions, which are disproportionately comprised of small particles, it is possible that the design is utilizing changes in fine particulates pollution. This is consistent with the significant effects of the regulation-induced TSPs reductions on infant mortality documented in Chay and Greenstone (2003b), which utilizes identical variation in TSPs changes. Further, several of the studies that have documented an association between PM-10 and human health did not use actual measures of PM-10 concentrations.

[13] TSPs consist of all particles with diameters less than or equal to 40 micrometers (μm). PM-10 particulates have diameters less than or equal to 10 μm. Data on PM-10 concentrations are not available for the 1969-1974 period.

Instead, these studies multiplied TSPs concentrations by a constant factor to obtain PM-10 measures (e.g., Pope, Dockery and Schwartz (1995)).

6. Conclusion

This study examined the adult health impact of a large, one-year reduction in TSPs air pollution induced by the Clean Air Act of 1970. While we found that regulatory intensity is associated with large TSPs reductions, it has little systematic association with reductions in either adult or elderly mortality. These results imply that the regulation-induced reduction in TSPs is not associated with improvements in adult mortality. We interpret these findings with caution due to the imprecision of the estimated effects and evidence of significant problems with the research design. An additional limitation of the study is that it cannot assess the long-term impacts of chronic pollution exposure on human health. We conclude that the design problems documented in this study are likely to be even more severe in the cross-sectional designs commonly used in the literature.

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Table 1: Demographics by 1971 TSPs Level Quartile Groups for People Over 50

TSP Range	Under 58.16	58.2 - 75.4	75.4 - 92.3	Over 92.3	All Counties
Counties in Sample	125	125	125	126	501
Demographics of Counties in Sample					
Population age 50 to 120 in Sample	3,480,292	5,632,658	8,128,407	13,820,937	31,062,294
Percent White	91.69%	91.47%	90.89%	88.44%	90.00%
Percent Black	4.47%	7.78%	8.60%	10.69%	8.92%
Percent Other	3.84%	0.75%	0.51%	0.87%	1.09%
Percent Male	45.42%	44.88%	44.69%	44.35%	44.65%
Percent Age 50-54	22.04%	23.38%	23.50%	22.94%	23.06%
Percent Age 55-59	19.37%	20.31%	20.48%	20.38%	20.28%
Percent Age 60-64	16.97%	17.17%	17.29%	17.37%	17.27%
Percent Age 65-69	14.32%	13.67%	13.68%	13.92%	13.86%
Percent Age 70-74	11.26%	10.50%	10.48%	10.66%	10.65%
Percent Age 75-79	8.06%	7.49%	7.39%	7.54%	7.55%
Percent Age 80-84	4.91%	4.58%	4.45%	4.48%	4.54%
Percent Age Over 85	3.07%	2.90%	2.73%	2.70%	2.79%
TSPs Concentration	48.6	67.8	83.2	120.2	93.0
Per Capita Employment, Transfers and Health Expenditures of Counties in Sample					
Total Employment Population / Population	43.38%	45.70%	46.12%	51.17%	48.02%
Manufacturing Employment / Population	7.72%	9.55%	9.25%	11.49%	10.14%
Income	$10,894	$11,679	$11,766	$11,797	$11,666
Net Earnings	$8,042	$8,893	$9,037	$8,950	$8,859
Transfer Payments	$1,155	$1,042	$1,078	$1,216	$1,143
Income Maintinance Benefit Payments	$136	$130	$153	$210	$173
Unemployment Insurance	$100	$80	$84	$89	$87
Retirement Benefits	$919	$833	$841	$917	$883
Total Medical Payments	$191	$177	$203	$236	$212
Medicare Payments	$105	$96	$94	$111	$103
Public Assistance Medical Care	$80	$77	$104	$122	$105
SSI	$40	$30	$32	$44	$38
Family Assistance	$67	$71	$88	$118	$96
Food Stamps	$17	$18	$15	$23	$19
Total Deaths 50 to 120 in Sample	108,862	170,827	247,643	442,032	969,364
Mortality Per 10,000 residents by Age in Sample					
Residents Age 50-54	83.9	83.3	85.6	92.5	88.1
Residents Age 55-59	127.6	128.7	130.0	138.9	133.5
Residents Age 60-64	191.0	192.3	195.4	206.5	199.3
Residents Age 65-69	278.3	282.5	287.9	297.7	290.2
Residents Age 70-74	408.7	424.3	429.2	447.7	434.3
Residents Age 75-79	644.0	656.9	660.4	686.7	669.6
Residents Age 80-84	967.4	971.4	988.4	1025.6	999.5
Residents Age Over 85	1738.9	1681.8	1741.0	1762.2	1739.5

Notes: The income, medical expenditure and transfer payments are for everyone in the county. The demographic information is for adults over 50. The death rates are deaths per 10,000 residents in the age category. Data is only presented for counties for which TSPs data was collected from 1970-1972. Regulated vs unregulated refers to 1971 regulatory status which was based on 1970 TSPs levels.

Table 2: Cross-Sectional Estimates of the Association between Mean TSPs and Adult Mortality Rates
(estimated standard errors in parentheses)

	Adult Deaths per 10,000 Residents			
	(1)	(2)	(3)	(4)
Adults Aged Over 50				
1969 Cross-Section	**0.183**	**0.106**	0.024	0.012
	(0.062)	**(0.037)**	(0.030)	(0.023)
	[397,.04]	[397,.57]	[351,.75]	[351,.86]
1970 Cross-Section	0.112	**0.087**	0.022	0.008
	(0.068)	**(0.044)**	(0.024)	(0.014)
	[501,.02]	[501,.58]	[451,.74]	[451,.87]
1971 Cross-Section	0.088	0.058	-0.047	-0.020
	(0.091)	(0.049)	(0.025)	(0.026)
	[501,.01]	[501,.57]	[463,.74]	[463,.86]
1972 Cross-Section	0.102	0.007	**-0.130**	-0.057
	(0.125)	(0.076)	**(0.050)**	(0.034)
	[501,.01]	[501,.60]	[461,.72]	[461,.85]
1973 Cross-Section	0.208	0.109	-0.054	0.043
	(0.129)	(0.087)	(0.061)	(0.043)
	[495,.02]	[495,.62]	[459,.74]	[459,.86]
1974 Cross-Section	0.126	0.035	**-0.157**	-0.057
	(0.115)	(0.073)	**(0.050)**	(0.040)
	[489,.01]	[489,.61]	[461,.75]	[461,.87]
Elderly Aged 65-84				
1969 Cross-Section	**0.419**	**0.309**	0.060	0.027
	(0.123)	**(0.100)**	(0.061)	(0.050)
1970 Cross-Section	**0.275**	**0.205**	0.051	0.050
	(0.130)	**(0.091)**	(0.047)	(0.034)
1971 Cross-Section	0.230	0.197	-0.036	0.062
	(0.190)	(0.135)	(0.062)	(0.058)
1972 Cross-Section	0.238	0.092	-0.182	-0.040
	(0.260)	(0.175)	(0.103)	(0.070)
1973 Cross-Section	0.350	0.252	0.007	0.186
	(0.249)	(0.175)	(0.126)	(0.096)
1974 Cross-Section	0.219	0.164	-0.154	0.018
	(0.208)	(0.159)	(0.106)	(0.089)
Age Distribution	N	Y	Y	Y
Gender	N	Y	Y	Y
Race	N	Y	Y	Y
Income, Employment	N	N	Y	Y
Income Assistance	N	N	Y	Y
Medical Expenditures	N	N	Y	Y
State Fixed Effects	N	N	N	Y

Notes: See notes to Table 1. Numbers in brackets are the number of counties and R-squareds of the regressions, respectively. The potential sample is limited to the 501 counties with TSPs data in 1970, 1971 and 1972. Sampling errors are estimated using the Eicker-White formula to correct for heteroskedasticity. Regressions are weighted by county populations. The control variables are listed in Table 1. State Effects are separate indicator variables for each state. Bold text indicates that the null hypothesis that the estimate is equal to zero can be rejected at the 5% level.

Table 3: Fixed Effects Estimates of Association between Mean TSPs and Adult Mortality Rates
(estimated standard errors in parentheses)

	Adult Deaths Aged Over 50 per 10,000 Residents				Elderly Deaths Aged 65-84 per 10,000 Residents			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
1969-1974 Pooled								
Mean TSPs	**0.070**	-0.017	-0.015	**-0.021**	**0.195**	**-0.036**	**-0.041**	**-0.048**
	(0.021)	(0.010)	(0.010)	**(0.009)**	**(0.053)**	**(0.018)**	**(0.019)**	**(0.019)**
R-squared	0.91	0.94	0.95	0.96	0.83	0.91	0.92	0.93
Number of Counties	386	386	330	330	386	386	330	330
1971-1972 First Differenced								
Mean TSPs	-0.042	-0.022	-0.028	-0.050	-0.065	-0.031	-0.044	-0.074
	(0.035)	(0.035)	(0.037)	(0.027)	(0.059)	(0.057)	(0.065)	(0.059)
R-squared	0.01	0.07	0.14	0.27	0.00	0.04	0.09	0.22
Number of Counties	501	501	458	458	501	501	458	458
County Fixed Effects	Y	Y	Y	Y	Y	Y	Y	Y
Age Distribution	N	Y	Y	Y	N	Y	Y	Y
Gender	N	Y	Y	Y	N	Y	Y	Y
Race	N	Y	Y	Y	N	Y	Y	Y
Income, Employment	N	N	Y	Y	N	N	Y	Y
Income Assistance	N	N	Y	Y	N	N	Y	Y
Medical Expenditures	N	N	Y	Y	N	N	Y	Y
Year Effects	N	Y	Y	Y	N	Y	Y	Y
State-Year Effects	N	N	N	Y	N	N	N	Y

Notes: In the first panel the regressions are based on pooled data and include county indicator variables as controls. In the second panel the regressions are based on first-differenced data. Standard errors are estimated using the Eicker-White formula to correct for heteroskedasticity. Regressions are weighted by populations in each county and year in the first panel and the sum of populations in 1971 and 1972 in the second panel. Bold text indicates that the null hypothesis that the estimate is equal to zero can be rejected at the 5% level.

Table 4: County demographics in 1971 by Regulatory Status

	All Counties			Counties 1970 TSP (45-105)			Counties 1970 TSP (60-90)		
	Not Regulated	Regulated	T-stat	Not Regulated	Regulated	T-stat	Not Regulated	Regulated	T-stat
Counties in Sample	231	270		172	149		85	91	
Demographics of Counties in Sample									
Population age 50 to 120	7,509,465	23,552,829		6,794,020	8,583,972		3,126,008	5,394,973	
Percent White	90.97%	89.68%	1.37	91.64%	90.53%	0.98	90.31%	90.92%	-0.40
Percent Black	6.75%	9.61%	-3.69	7.19%	8.89%	-1.51	8.65%	8.65%	0.00
Percent Other	2.28%	0.70%	2.66	1.17%	0.58%	3.14	1.04%	0.44%	2.75
Percent Male	44.91%	44.57%	1.98	44.60%	44.80%	-1.06	44.77%	44.87%	-0.35
Percent Age 50-54	22.03%	23.40%	-4.41	21.91%	23.69%	-4.59	23.51%	23.58%	-0.14
Percent Age 55-59	19.68%	20.47%	-4.92	19.62%	20.49%	-4.34	20.27%	20.42%	-0.71
Percent Age 60-64	17.30%	17.26%	0.51	17.29%	17.18%	1.22	17.09%	17.20%	-1.04
Percent Age 65-69	14.33%	13.71%	4.43	14.35%	13.61%	4.27	13.58%	13.74%	-0.82
Percent Age 70-74	11.14%	10.50%	4.29	11.21%	10.35%	4.57	10.41%	10.45%	-0.19
Percent Age 75-79	7.86%	7.45%	3.65	7.93%	7.36%	3.95	7.49%	7.39%	0.59
Percent Age 80-84	4.73%	4.48%	3.55	4.76%	4.49%	2.90	4.65%	4.46%	1.55
Percent Age Over 85	2.94%	2.74%	4.08	2.94%	2.82%	1.88	3.00%	2.77%	2.72
TSPs Concentration	65.4	101.8	-15.62	67.6	81.2	-7.35	67.6	78.6	-5.85
Per Capita Employment, Transfers and Health Expenditures of Counties in Sample									
Total Employment / Popu	41.63%	50.07%	-5.62	41.56%	47.75%	-4.54	45.35%	46.68%	-0.89
Manufacturing Employmen	7.25%	11.07%	-9.52	7.38%	9.93%	-5.01	8.18%	9.46%	-2.03
Income	$11,130	$11,837	-3.43	$11,231	$11,471	-1.00	$11,097	$11,455	-1.13
Net Earnings	$8,264	$9,050	-5.05	$8,321	$8,868	-2.94	$8,549	$8,876	-1.32
Transfer Payments	$1,204	$1,123	2.64	$1,224	$995	6.39	$1,036	$981	1.50
Income Maintinance Bene	$175	$172	0.28	$180	$125	4.88	$140	$119	2.23
Unemployment Insurance	$85	$88	-0.59	$84	$81	0.52	$80	$77	0.44
Retirement Benefits	$944	$863	3.71	$959	$789	6.49	$816	$786	1.15
Total Medical Payments	$236	$204	2.68	$245	$161	6.67	$181	$161	1.74
Medicare Payments	$111	$101	2.73	$115	$86	6.46	$94	$88	1.38
Public Assistance Medic	$119	$100	2.05	$125	$70	5.53	$82	$68	1.70
SSI	$46	$35	3.35	$47	$27	5.58	$42	$26	3.76
Family Assistance	$94	$97	-0.51	$97	$67	4.27	$70	$65	0.97
Food Stamps	$18	$20	-1.43	$18	$19	-0.44	$19	$16	0.85
Total Deaths Over 50 in Sample	231,950	737,414		210,826	260,937		96,098	163,802	
Mortality Per 10,000 residents by Age in Sample									
Residents Age 50-54	84.3	89.3	-3.17	84.8	87.0	-1.04	84.1	86.4	-0.83
Residents Age 55-59	127.7	135.3	-3.86	128.4	131.2	-1.11	129.5	132.3	-0.77
Residents Age 60-64	190.7	202.0	-4.41	191.5	196.6	-1.58	197.3	196.9	0.08
Residents Age 65-69	278.3	294.0	-4.74	278.7	287.4	-2.10	287.1	287.1	0.00
Residents Age 70-74	414.8	440.5	-5.27	416.3	427.8	-1.93	427.3	426.3	0.13
Residents Age 75-79	648.0	676.5	-4.23	649.6	655.0	-0.65	656.5	659.3	-0.26
Residents Age 80-84	969.1	1009.2	-4.31	969.4	979.3	-0.87	961.0	977.0	-1.03
Residents Age Over 85	1727.0	1743.5	-0.95	1736.1	1683.5	2.49	1675.3	1682.4	-0.26

Notes: The income, medical expenditure and transfer payments are for everyone in the county. The demographic information is for adults over 50. The death rates are deaths per 10,000 residents in the age category. Data is only presented for counties for which TSPs data was collected from 1970-1972. Regulated vs unregulated refers to 1971 regulatory status which was based on 1970 TSPs levels.

Table 5: Reduced-Form Estimates of the Impact of 1972 Nonattainment Status on 1971-1972 Changes in TSPs Pollution and Mortality Rates Among Adults Aged Over 50
(estimated standard errors in parentheses)

	1971-1972 Change in Mean TSPs Air Pollution					1971-1972 Change in Mortality per 10,000 Residents				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
All Counties										
Nonattainment	-11.36	-10.37	-9.13	-7.42	-16.10	0.17	-0.45	0.09	0.09	-8.97
	(2.68)	(2.25)	(2.04)	(2.22)	(6.43)	(1.60)	(1.53)	(1.43)	(1.78)	(5.02)
R-squared	0.05	0.08	0.11	0.31	0.08	0.00	0.07	0.14	0.27	0.09
Counties in Sample	501	501	458	458	501	501	501	458	458	501
Counties 1970 TSPs 45-105										
Nonattainment	-5.02	-5.27	-4.85	-6.14	-8.57	0.09	0.34	0.75	2.29	-6.38
	(3.02)	(2.59)	(1.78)	(1.79)	(6.21)	(1.68)	(1.69)	(1.63)	(1.87)	(5.22)
R-squared	0.03	0.13	0.18	0.42	0.19	0.00	0.11	0.17	0.31	0.13
Counties in Sample	321	321	296	296	321	321	321	296	296	321
Counties 1970 TSPs 60-90										
Nonattainment	-9.32	-8.36	-4.31	-5.89	-5.93	0.88	0.17	1.89	-3.20	-8.18
	(3.78)	(2.94)	(1.95)	(2.35)	(7.30)	(2.35)	(2.30)	(2.26)	(3.02)	(7.40)
R-squared	0.09	0.23	0.25	0.59	0.31	0.00	0.14	0.26	0.44	0.17
Counties in Sample	176	176	162	162	176	176	176	162	162	176
Age Distribution	N	Y	Y	Y	Y	N	Y	Y	Y	Y
Gender	N	Y	Y	Y	Y	N	Y	Y	Y	Y
Race	N	Y	Y	Y	Y	N	Y	Y	Y	Y
Income, Employment	N	N	Y	Y	N	N	N	Y	Y	N
Income Assistance	N	N	Y	Y	N	N	N	Y	Y	N
Medical Expenditures	N	N	Y	Y	N	N	N	Y	Y	N
State-Year Fixed Effects	N	N	N	Y	N	N	N	N	Y	N
Nonattain Interactions	N	N	N	N	Y	N	N	N	N	Y

Notes: The dependent variables are the 1971-72 first-differences of mean TSPs pollution and 1971-72 first-differences in deaths among adults aged over-50 per 10,000 residents. Nonattainment in 1972 is an indicator variable equal to one if the county had TSPs concentrations above the federal air quality standard for TSPs in 1970. Standard errors are estimated using the Eicker-White formula to correct for heteroskedasticity. Regressions are weighted by populations numbers in each county and year.

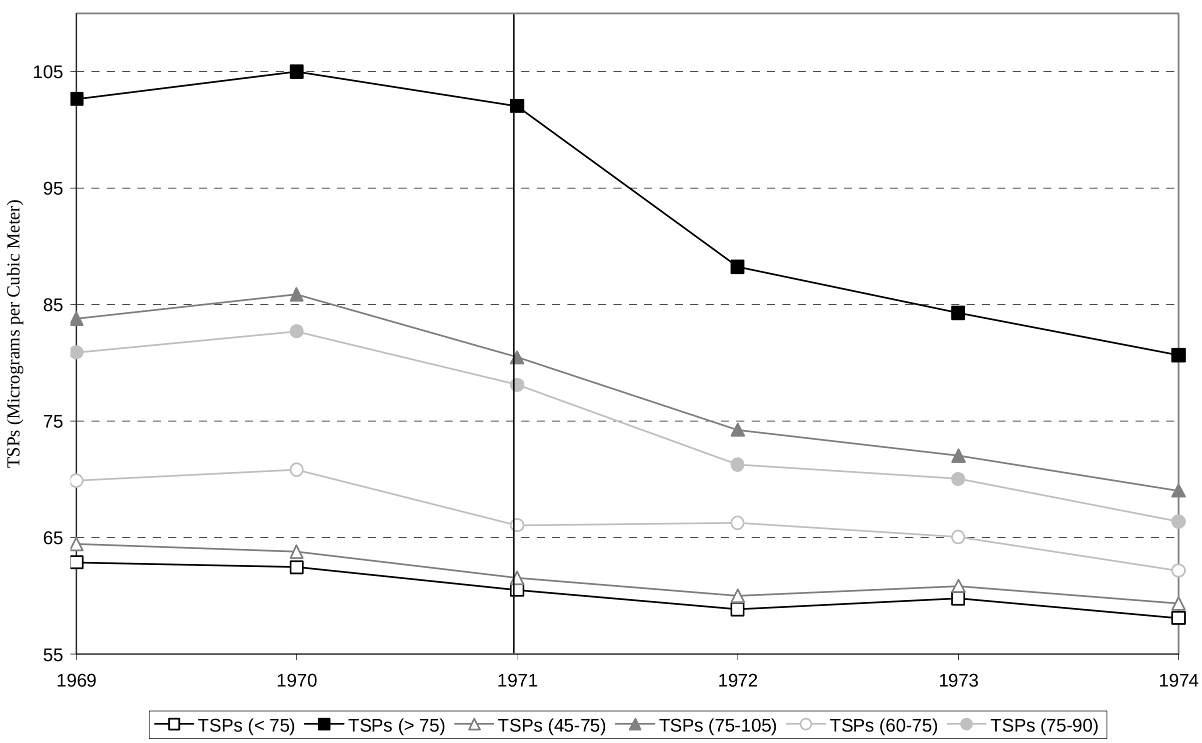
Table 6: Instrumental Variables Estimates of the Effect of Mean TSPs on Adult Mortality Rates, Based on 1971-72 Changes Using 1972 Nonattainment Status as Instrument
(estimated standard errors in parentheses)

	1971-1972 Change in Deaths per 10,000 Residents				
	(1)	(2)	(3)	(4)	(5)
All Counties					
Adults Aged Over 50	-0.015	0.044	-0.010	-0.012	0.557
	(0.140)	(0.146)	(0.157)	(0.240)	(0.371)
Elderly Aged 65-84	0.293	0.336	0.250	0.351	0.669
	(0.270)	(0.276)	(0.306)	(0.450)	(0.596)
Counties in sample	501	501	458	458	501
Counties 1970 TSPs 45-105					
Adults Aged Over 50	-0.018	-0.065	-0.154	-0.373	0.744
	(0.334)	(0.324)	(0.342)	(0.335)	(0.804)
Elderly Aged 65-84	0.647	0.337	0.240	-0.633	0.562
	(0.832)	(0.649)	(0.687)	(0.647)	(0.831)
Counties in sample	321	321	296	296	321
Counties 1970 TSPs 60-90					
Adults Aged Over 50	-0.094	-0.020	-0.438	0.544	1.380
	(0.252)	(0.276)	(0.581)	(0.469)	(2.004)
Elderly Aged 65-84	0.004	-0.061	0.167	0.090	0.115
	(0.476)	(0.524)	(0.975)	(1.003)	(0.794)
Counties in sample	176	176	162	162	176
Age Distribution	N	Y	Y	Y	Y
Gender	N	Y	Y	Y	Y
Race	N	Y	Y	Y	Y
Income, Employment	N	N	Y	Y	N
Income Assistance	N	N	Y	Y	N
Medical Expenditures	N	N	Y	Y	N
State-Year Fixed Effects	N	N	N	Y	N
Nonattainment Interactions	N	N	N	N	Y

Notes: Results are from two-stage least squares estimation using 1971-72 first-differences, with changes in mean TSPs instrumented by nonattainment status in 1972. Estimated standard errors allow for heteroskedasticity. Regressions are weighted by populations in each county and year.

Figure 1: 1969-1974 Trends in TSPs Pollution, by 1972 Nonattainment Status

A. TSPs Trends by 1970 TSPs Levels



B. Nonattainment-Attainment TSPs Differences by 1970 TSPs Ranges

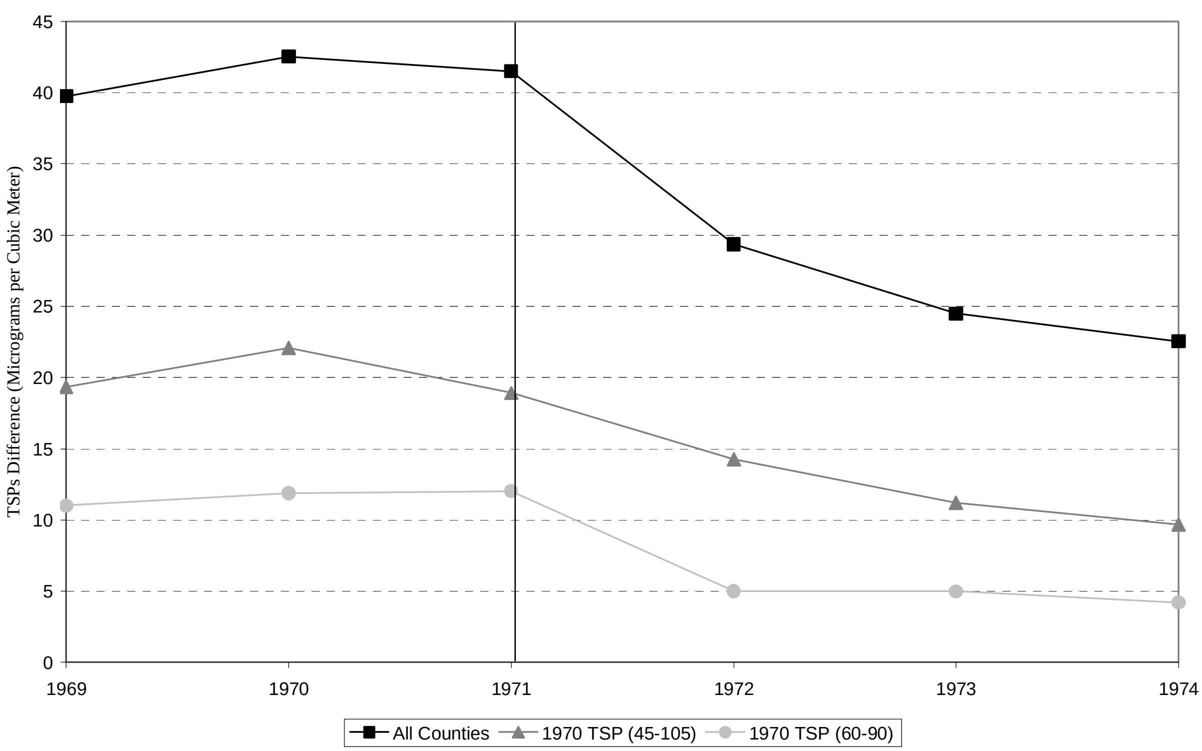


Figure 2: Trends in Mortality Rates Among Adults Over Age 50, by 1972 Nonattainment Status

A. Trends in Mortality Rates by 1970 TSPs Levels

B. Nonattainment-Attainment Mortality Differences by 1970 TSPs Ranges

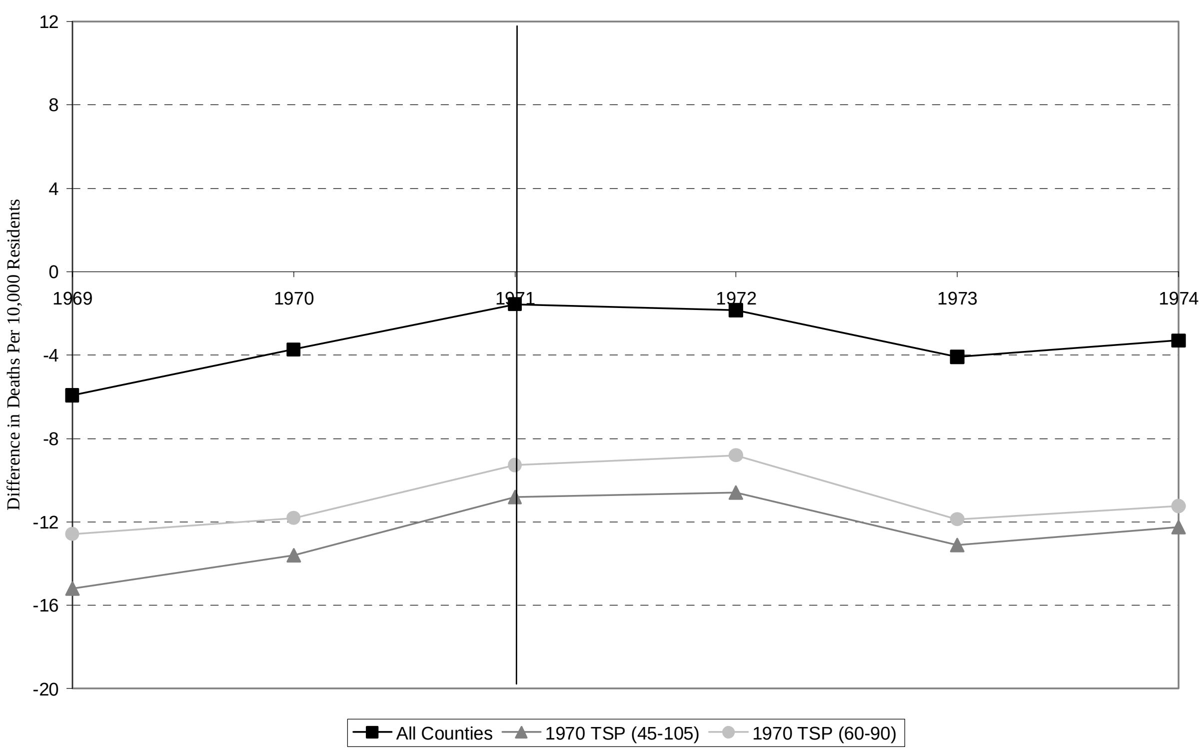
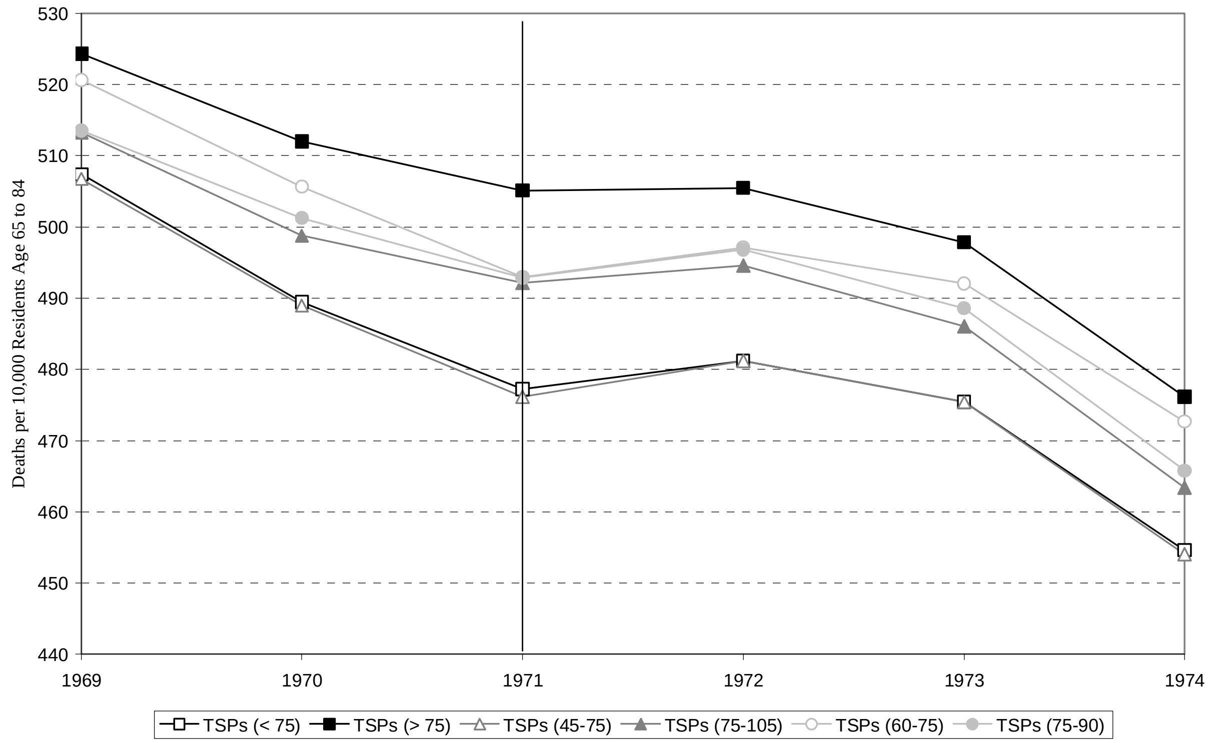


Figure 3: Trends in Mortality Rates Among Elderly Aged 65-84, by 1972 Nonattainment Status

A. Trends in Mortality Rates by 1970 TSPs Levels



B. Nonattainment-Attainment Mortality Differences by 1970 TSPs Ranges