Effects of Early Childhood Exposure to Pollution on Crime: Evidence from 1970 Clean Air Act

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Abstract

Past literature has shown that 1970 amendments to the Clean Air Act (CAA) led to significant reduction in air pollution early 1970s, and that it had positive infant health consequences for the cohorts treated by CAA. Because effects of in-utero and early childhood conditions are persistent, and the health effects can remain latent for years, CAA may impact the future adult outcomes. In this paper, I investigate the impact of the CAA on the future crime. In a difference-in-differences framework, I find that the cohorts that were born in the year of the CAA's first implementation commit fewer crimes 15 to 24 years later. The magnitude of this impact is about 4 percent. Property crimes rather than violent crimes are impacted. I also estimate that CAA reduced the ambient air pollution by 14 percent. These reduced form estimates suggest that a one percent reduction in air pollution reduces future crime rate by 0.3 percent.

Keywords: Pollution, Crime, Birthweight, Education, Employment Status, Earnings

JEL Codes: I15, I25, J24, K14, K42, Q53

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I. INTRODUCTION AND BACKGROUND

It has been documented that air pollution is one of the major causes of death and several diseases at the global level by the World Health Organization (WHO). For example, around 4.2 million premature deaths globally are linked to ambient air pollution in year 2016. Several past papers which study the health consequences of air pollution find that it negatively impacts birth outcomes, and it increases individuals' tendency to suffer from asthma and other respiratory illnesses (Currie and Neidell, 2005; Currie et al., 2009; Currie and Schmeider, 2009; Neidell, 2004; Knittel et al., 2016; Schlenker and Walker, 2015). Another set of papers provides evidence for pollution's impact on individuals' future outcomes. For example, many studies have found that early life exposure, such as in utero or during early childhood, to air pollution has adverse adult outcomes in the future. The negative future effects include worse mental health (Grandjean et al., 1998; Debes et al., 2006), education and test scores (Bharadwaj et al., 2017), school absence rates (Currie et al., 2009) and some other measures of human capital such as, labor supply, cognition and productivity (Zivin and Neidel, 2012, 2013).

In this line of research, an influential paper by Chay and Greenstone (2003a) shows that the reduction in air pollution induced by the 1970 Amendments to the Clean Air Act (CAAA) improved the health of the cohorts impacted by it. Using the same variation in the extent of air pollution generated by the 1970 CAAA, Isen et al. (2017) show that the reduction in air pollution significantly increased individuals' earnings and labor force participation when they are 30 years old. In this paper, I follow the implications of these two papers and investigate the impact of 1970 CAAA on future criminal

activity. Specifically, if CAAA increases individuals' opportunities in the legal labor market in the future, then it would increase the cost of committing crime as well[1].

The trends in ambient air pollution and the crime rates, which are depicted in Figure 1, provide additional motivation for my study. The solid-thick line represents the average pollution concentration in the whole nation (measured on the left vertical axis). The air pollution level was high in late 1960s but decreased in early 1970s around the time of the implementation of the CAAA. The decrease continued until 1990s. In the same figure, with the dashed-thin line, I depict the property crime rate 20 years to the future (measured on the right vertical axis). Those future years are shown in the upper horizontal axis. The figure astonishingly shows that the reduction in TSPs in early 1970s corresponds to lower crime rates in about 20 years in 1990s.[2] That is cohorts born in low pollution years committed fewer crimes in adulthood.[3]

In this paper, I investigate whether the implementation of 1970 CAAA caused the decreases in the crime rate in the future using a difference-in-differences strategy. Particularly, the counties whose maximum level of air pollution were unacceptably high as of 1970 were designated as a *nonattainment county*, and they were forced to reduce their air pollution levels by 1975-1977.[4] These counties constitute the treatment group. Other counties, whose air pollution was below the allowable limit, were classified as *attainment counties,* and they were not required to make any changes, thus,

[1] Becker (1968), was the first paper to compare the potential benefits with cost of committing crime. Several past papers also show a positive impact of unemployment rate on crime (Altindag, 2012; Nordin and Almen, 2017), and a negative relationship between earnings and crime (Witt et al., 1998; Mocan and Unel, 2011)

[2] US experienced one of the greatest declines in crime rate in early 1990's. Many papers in the past have studied about the factors that could explain this sudden fall in the crime rate in early 1990s. the main factors that seem to explain this reduction in crime are increase in forces (police), increased imprisonment, the descent of crack, racial profiling, concealed weapons law, and legalized abortion (Donahue and Levitt, 2001; Levitt, 2004; Levitt and Miles, 2006).

[3] The effect of early childhood exposure to air pollution on crime has not been extensively studied so far. Few papers argue that exposure to lead has a contemporaneous impact on the violent crime because of the aggressive and violent behavior lead induces (Needleman et al., 1996; Stretesky and Lynch, 2004).

[4] States had to pay a penalty to the Federal government if they did not comply with the standards set by the act.

used as the control group. Though the act was signed in December 1970, all the states did not start implementing it until January 1972 because the states were first asked to prepare and submit *State Implementation Plans (SIPs)* based on Air Quality Standards set by the Act.[5] Thus, the post-treatment period starts with 1972.[6] Figure A1 shows the annual national trends in average total suspended particulates (TSPs) for nonattainment and attainment counties separately. It shows a significant drop in the TSP level of the attainment counties after the implementation of 1970 CAAA in the attainment counties as compared to the TSP level of attainment counties, which is fairly constant over the period. In my estimation, I compare the treated and control group's future crime rates. In my regressions, I use the arrest rates instead of the crime rates. Using the arrest rates is advantageous because the ages of those who are arrested are known, and therefore, using the arrest rate allow me to identify whether a particular cohort is treated by the CAAA. In my sample, I use the cohorts who were born around the implementation of the 1970 CAAA (1967-1975), and I investigate whether the implementation of CAAA affected the crimes they commit 15-24 years later, i.e., in 1982-1999.

My results indicate that CAAA reduced the crime rates of the treated groups by 4 percent. That is, the counties which were designated as non-attainment in 1970 suffered fewer crimes in 15-24 years compared to the control counties. This impact applies to the property crimes rather than the violent crimes. I also find that CAAA reduced the air pollution by 14 percent. These reduced form results together imply that a one percent pollution reduction reduces property crime by 0.3 percent. In an extension analysis, I show that the decrease in the pollution only in a cohort's year of birth or in the following year reduces their criminal activity in the future. That is, for a cohort born in 1972, only

[5] See Appendix Table A1 for the 1970 CAAA timeline.
[6] See Appendix Figure A1 that shows the pollution levels of nonattainment counties vs. attainment counties from 1965-1989.

the air pollution levels in 1972 and 1973 were significant determinants of future crimes, but not the pollution in other years.

My paper is one of the first papers that document the effect of in-utero and early childhood exposure to pollution on the adult crime rate. A handful of other studies in the past literature also investigated the effect of pollution on crime, but their main focus was on the contemporaneous changes in the crime, not the future crime (Burkhardt et al., 2019; Stretesky and Lynch, 2004; Needleman et al., 1996). There is little evidence on the long-term effects of pollution on crime. Closest to my paper are Mielke and Zahran (2012), and Reyes (2015). Reyes (2015) used state-level variation in lead with only about 8000 individuals in their dataset. Mielke and Zahran (2012) looked at the 22 years latent effect of lead exposure on crime. The contribution of my paper to the existing literature is two-fold. First, both the papers are looking at the effect of lead, which has a direct impact on the violent crime, as lead increases the aggressiveness. Whereas, my paper uses another mechanism, i.e., through human capital accumulation, to show the effect on property crime. Second, as opposed to these papers I am looking at the impact of a policy change (1970 CAAA) with the TSP pollutant for ages ranging from 15-24 years old, which gives me a more well defined robust relationship of the policy change with the adulthood crime.

The structure of the rest of the paper is as follows: Section II presents the biological mechanism of TSPs concentration. Section III briefly provides the details of the Clean Air Act. Section IV describes the data and the summary statistics. Section V discusses the conceptual framework and the methodology used to answer my research question. Section VI provides the empirical results. Section VII shows various robustness checks. Finally, section VIII concludes.

II. BIOLOGICAL MECHANISM OF TSPs CONCENTRATION

I use TSP to measure the early-life exposure to pollution because this was the type of pollution (particulate matter) monitored by the EPA, at the time the 1970 amendment was passed. All suspended airborne solid or liquid particles smaller than 100 micrograms per cubic meter are included in the TSPs. There are two major sources of TSPs: human sources (such as industrial activities and motor vehicles), and natural sources (such as dirt and dust). Since it includes all the particles under 100 micrometers in size, some of these particles are larger and heavier and thus, settle down to the ground quickly, not harming humans as they are less likely to be inhaled. Smaller particles in the TSP (specifically the ones less than 10 micrometers in size), on the other hand, are very harmful for human beings when inhaled, because they penetrate deep into the lungs and disrupt the proper functioning of the respiratory and the lungs system. Also, according to the EPA, the smaller particles collect into the tiny air sacs of the lungs, where oxygen enters the bloodstream. Since, these particles can be transferred into the bloodstream from the lungs, the adverse health effects due to this are there during in-utero as well.[7]

All these biological impacts of the inhaled TSPs may deteriorate the cognitive ability of the child when he/she enters the adulthood. Thus, the harmful neurological effect or the direct health deterioration caused by the in-utero and early-life exposure to pollution may lead to lower educational attainment and lower earnings. This may further result in an increase in crime as it will be less costly to commit crime for people with lower earning. Later, I provide evidence to show how the exposure to pollution only in the birth year and 1 year after the birth affects the long-run outcome (crime in this case) for a particular cohort in a certain county.

[7] See US EPA (2009)

III. THE HISTORY OF CLEAN AIR ACT

The Clean Air Act is the US federal law designed to monitor and control the air pollution level in the Unites States and is the largest and most comprehensive environmental law in the country. It is administered by the EPA and requires EPA to adopt and enforce certain regulations for the air pollution levels to protect the residents of the US from exposure to airborne toxins and pollutants considered to be lethal to human health. This act was first passed in 1963 and there have been various amendments to this act since then. But there were three major amendments in 1970, 1977 and 1990.

The amendment of 1970 was very significant as it resulted in a major shift in the role of the federal government in the control of air pollution. When this law was first passed in 1963, the federal government fully authorized the state and the local government to develop and enforce the regulations in their respective areas to control the increasing air pollution. But the state and the local governments were not that successful in decreasing the pollution levels in their areas. Thus, the legislation of 1970 CAAA authorized the federal regulations along with the state regulations to limit emissions from both industrial and mobile sources. By doing so, EPA established National Ambient Air Quality Standards (NAAQS), which specify the maximum-allowable limit for six criteria pollutants. Based on these standards and the 1970 TSP level the counties were given nonattainment or attainment status. The counties exceeding the maximum acceptable limit were designated as nonattainment counties and were forced to reduce their pollution level below the limit by the year 1975 and had to pay certain amount of penalty to the state or the federal government or both in some cases if they were not able to comply with the standards in the given time frame.[8] The counties with

[8] According to the CAAA, "EPA can withhold federal aid for the state air pollution control program, for highway construction and for construction of sewage treatment plants. EPA also can ban awarding of permits for construction of major new and modified sources of the pollutant for which an area has not attained the standard. In addition, EPA can produce its own plan for the area."

TSP levels below the limits specified by the EPA were legally required to do nothing, just had to maintain their lower pollution levels.[9]

IV. DATA

To conduct my analysis, I use county level data for my primary variables. I combine ambient air pollution data from the Environmental Protection Agency (EPA) with crime data from the FBI's (Federal Bureau of Investigation) Uniform Crime Reports (UCR) program, for my analysis. In this section, I describe the datasets, and any other additional details on the data can be found in the Data Appendix.[10]

A. Air Pollution

I use the Total Suspended Particulates (TSPs) as the measure for air pollution from the EPA's air pollution monitoring sites. I focus on TSPs as the measure because my analysis requires me to take the pollution data for the time period 1967-1990 and TSP is the only archaic measure of particulate matter that EPA used to monitor till 1986. It includes all the airborne suspended particles (solid or liquid) which are smaller than 100 micrometers in size. After 1986, EPA shifted their regulatory attention towards smaller particles in air and started measuring PM10 (smaller than 10 micrometers) and PM 2.5 (smaller than 2.5 micrometers) from 1987 and 1997, respectively. I follow Chay and Greenstone (2003a, 2003b) to measure the county-level average annual estimates of TSPs concentration.[11]

[9] Refer Greenstone, 2003a, 2003b for more details on 1970 CAAA.
[10] Data sources description on other control variables is also provided in the data appendix.
[11] Precisely, the yearly TSPs concentration we used is the weighted average of the annual arithmetic means of the TSP concentration measured at each monitor site in the county, the number of observations at each monitor per year being used as the weights.

EPA established NAAQS (National Ambient Air Quality Standards) to specify the minimum requirements for six criteria air pollutants[12] at county level.[13] The main aim of the 1970 Act was to reduce the local air pollution according to the NAAQS by 1975. So, I construct a measure of TSP to assign the counties "attainment-nonattainment" status on the basis of two primary thresholds set by NAAQS standards for TSPs concentration: (i) annual geometric mean of 75 $\mu g/m^3$, or (ii) the second highest 24-hour concentration of 260 $\mu g/m^3$. If the TSP concentration of a county exceeded either of the two thresholds, it was designated as the "nonattainment" county. Since no historical records could be found on the list of counties designated as nonattainment (as mentioned in Greenstone (2003b)), I assign the nonattainment-attainment status to the counties based on their 1970 TSP concentration level.[14]

All the counties in the US did not have air pollution monitors to capture the TSPs concentration level. Therefore, with the available data on the TSP readings for the year 1970, I classified a total of 565 counties, out of which 297 were nonattainment and 268 were attainment. And I take the average annual estimates of TSP from 1967-1975 in all of my specifications, focusing on the cohorts born 4 years prior to and 4 years after the implementation of the act.

B. Crime Rate

I use the county-level summary data file, "Uniform Crime Reporting Program Data: Arrests by Age, Sex, and Race" from the Uniform Crime Reporting Program Data Series provided by the United States Department of Justice, Federal Bureau of Investigation (FBI). The dataset available in these

[12] These criteria pollutants include particulate matter (TSP till 1986, PM10 and PM2.5 after that), sulfur dioxide, carbon monoxide, nitrogen dioxide, ozone, and lead.
[13] It is not clear from EPA as to whether these minimum requirements were set at the county level or at a more aggregate level of region. Following Greenstone (2003b) we assume it to be at the county level.
[14] Though the amendments were not implemented until the beginning of the year 1972, the counties are classified into the nonattainment status based on their 1970 TSP level because when the states were preparing their State Implementation Plans (SIPs) in 1971 for the submission to the federal government, they would have assigned the nonattainment status to their counties based on the latest available TSP level, which was for year 1970.

files provide information on the number of arrests by age, sex, race, and offenses. This information is reported to the FBI UCR Program every month by the police agencies in the counties of the US. Using this dataset, I calculate the arrest rates per 100,000 individuals, for the violent and property crimes (only serious offenses)[15] for the time period 1982-1999. Arrest data is being used as a proxy here for the crime data because the county level crime data by age and sex is not available. I take only those agencies in the counties which report at least one (serious) crime according to age and sex. Also, I limit my sample to only 15-24-years old, because all the ages before 15-years old and after 24-years old, are in groups (like 5-9, 10-14, 25-29, 30-34, etc.). Age groups cannot be used in my analysis as the year of birth is calculated from the age and the year of observation provided in the dataset. While using the arrest rates from 1982-1999, I focus on the individuals born between 1967 and 1975. Thus, each age group in a county is being observed for 9 years. Since I take only the agencies reporting at least one crime, when merging the crime data with the pollution data, I am left with 324 counties. In the majority of my specifications I use these 324 counties for the TSP pollutant data.

Table 1 provide the summary statistics for all the variables of interest in case of 1970 CAAA instrument. Columns 1 and 2 show the mean and standard deviation of these variables for the whole sample and the same is provided for the attainment counties in columns 3 and 4 and for the nonattainment counties in columns 5 and 6.

[15] Serious offenses include Murder, Rape, Robbery and, Assault under Violent Crimes and Burglary, Larceny and, Motor Vehicle Theft under Property Crimes.

V. CONCEPTUAL FRAMEWORK AND METHODOLOGY

Basic Econometric Model

I use difference-in-differences estimation strategy to obtain the effects of reduced pollution (TSP) caused by the 1970 CAAA on the crime rate (arrest rate) for the ages 15-24 years old at the county level data, using the following equation:

$$y_{c,t,a} = \beta_0 + \beta_1(Nonattainment_{c,1970} * Post1971) + \beta_2 X_{c,t} + \gamma_c + \theta_t + \mu_a + \epsilon_{a,c,t} \qquad (1)$$

where outcome $y_{c,t,a}$ is the arrest rate per 100,000 individuals for a given cohort of age *a* in county *c* as of year *t*.[16] For example, the outcome could be the property crime rate of all 18 years old in Orange County in 1997. This particular crime rate is then matched with the TSPs concentration in Orange County in 1979 (=1997-18). $Nonattainment_{c,1970}$ takes a value of one if the county has the nonattainment status and, zero otherwise. $Post1971$ indicates the post-treatment period, thus, it is equal to one if the year of birth is greater than 1971. Vector $X_{c,t}$ includes time-varying controls which may be correlated with the future crime rate and pollution at the same time, for example, county characteristics like percent black, total employment, income per capita, total transfers per capita, poverty rate, lagged prisoners per capita, and lagged police per capita. Some weather controls like precipitation, and temperature at county level are also included in vector *X*. γ_c stands for county fixed effects which control for unobserved time-invariant determinants of crime rate for cohorts born in a specific county; θ_t are year fixed effects; μ_a are age fixed effects and $\epsilon_{a,c,t}$ is the unobserved error term. In equation (1), β_1 is the main parameter of interest that provides an estimate of *difference-in-differences* for the effect of nonattainment status on future crime rates at the county level after the

[16] This form of my regression equation could the cause the problem of multiple hypothesis testing. To correct for that, I used Romano and Wolf's *rwolf* program to calculate the stepdown adjusted p-values.

implementation of the Clean Air Act regulations. I use a 4-year window around the implementation CAAA. That is, I compare the cohorts born in the nonattainment counties 4 years before and the cohorts born 4 years after the implementation of the act in 1972 with the cohorts born in the attainment counties.

Also, to obtain the impact of the 1970 CAAA on the pollution level (TSPs concentration), I estimate the following equation:

$$TSP_{c,t-a} = \delta_0 + \delta_1(Nonattainment_{c,1970} * Post1971) + \delta_2 X_{c,t} + \gamma_c + \theta_t + \mu_a + \epsilon_{a,c,t} \quad (2)$$

where $TSP_{c,t-a}$ is the TSPs concentration (air pollution) in county *c* and year of birth *t-a*. TSP concentration is regressed on the interaction of a dummy indicating the nonattainment status of the county with a dummy which is equal to one for the years after CAA implementation. Note that I control for time and county fixed effects. Thus, the parameter of interest δ_1, provides an estimate of *difference-in-differences* for the effect of nonattainment status on TSPs at the county level after the implementation of the Clean Air Act regulations. The standard errors in both equations (1) and (2) are clustered at the county level.

VI. EMPIRICAL RESULTS

Table 2 provide difference-in-differences estimates of the effect of nonattainment status on TSPs at the county level after the CAAA implementation obtained from the estimation of equation (2) for the period 1967-1975. The results are consistent with the past literature, showing a strong relation between the 1970 CAAA implementation and the ambient mean TSP level in nonattainment counties. The results show a reduction of around 13 $\mu g/m^3$ in TSPs level in nonattainment counties (as compared to the attainment counties) due to the CAAA implementation, amounting to about 14

percent reduction relative to the TSPs mean of around 90 $\mu g/m^3$ in nonattainment counties, which is consistent with the previous papers using the 1970 CAAA.

Table 3 presents the difference-in-differences estimates of the impact of nonattainment status after the implementation of the Clean Air Act regulations on future crime rates at the county level obtained from the estimation of equation (1) over the period of 1982-1999 for the cohorts who are 15-24 years old. In equation (1), the interaction term, $(Nonattainment_{c,1970} * Post1971)$, provides the difference-in-differences estimate, where $Nonattainment_{c,1970}$ indicates about the nonattainment status of a county and $Post1971$ stands for the post-treatment period. That is, the interaction term gives the change in the crime rate of the cohorts in nonattainment county as compared to the attainment county before and after the implementation of the act in 1972.

In Panel A of Table 3, I present these difference-in-differences estimates of the impact of the CAAA on the violent crime rates and, same for the property crime rates in Panel B. Estimates in all the columns of Panel A suggest that there is no significant impact on the violent crime rates. However, column (1) of Panel B shows that property crime rate is decreasing by 88 per 100,000 individuals for the nonattainment counties after the implementation of the 1970 act, which is significant at 5 percent level. Relative to the mean of 1,915 per 100,000 population for property crime, these results indicate that the CAAA reduced the property crime rates significantly, 15-24 years later in nonattainment counties by about 4 percent. Column (3) provides evidence that change in property rate is mainly coming from the decline in the larceny (decreasing by 76 per 100,000 individuals, which is significant at 1 percent level). Relative to the mean of 1,365 per 100,000 population for larceny, it decreased by approximately 5 percent. These reduced form estimates suggest that a 1 percent decrease in pollution (TSPs) at the time of birth, reduces property crime rates by 0.3 percent and larceny by 0.4 percent in the future.

Event Study Analysis

The interpretation of the reduced form difference-in-differences estimates presented in Table 3, relies on the assumption of "parallel trends", i.e. the crime rate in both the attainment and nonattainment counties would have trended in a parallel fashion if nonattainment were not treated. As standard in difference-in-differences analysis, I perform an event study analysis (Hoynes et al., 2015), to test for pre-trends, using the following regression equation:

$$Crime_{c,t,a} = \alpha_0 + \sum_{y=1967}^{1975} \alpha_1 (Nonattaunment_{c,1970} * 1[Year_{t-a} = y]) + \alpha_2 X_{c,t} + \gamma_c + \theta_{t-a} + \mu_a + \epsilon_{c,t} \quad (3)$$

where $Crime_{c,t,a}$ could be the property or violent crime rate per 100,000 population in county *c* in year *t* for cohorts 15-24 years old. $Nonattainment_{c,1970}$ takes a value of 1 if the county has been assigned nonattainment status in the year 1970, and $1[Year_{t-a} = y]$ are the dummies for the pollution years 4 years before and 5 years after the implementation of the act. The omitted year is 1971 because the act was implemented in 1972.

For the parallel trends assumption to hold, the estimates on the parameter of interest, α_1, prior to the act needs to be insignificant, thus showing that before the treatment both treatment and the control group are going in the same direction. I show this graphically, by plotting the estimates on the interaction variable between nonattainment status and year indicators for each year with their 95 percent confidence intervals. Figure 2 shows the estimates of equation (3) for the property crime rates, where it is evident that the cohorts born before 1972, i.e. before the implementation of the act have insignificant effects but, highly significant impact thereafter in years after the implementation

of the act.[17] Thus, there is no evidence of existence of any differences in the pre-trends in the property crime rate between attainment and nonattainment counties.[18]

VII. ROBUSTNESS CHECKS

A. Effect of Lagged TSP

Since the reduction in pollution in the nonattainment counties is permanent, thus, the CAAA will also impact the future pollution, which could have a contemporaneous impact on future crime rates. Therefore, to investigate whether the impacts I identify are due to the exposure to pollution either in the year of birth or early childhood and not in further years of life of a cohort, I regress the crime rate, for a particular age cohort, on the pollution in the year of birth along with the pollution in earlier years and the pollution in years after the birth. For example, for the cohort born in the year 1971, I regress including the TSPs level of 1971 (year of birth), 2 years prior to 1971, i.e. 1969 and 1970 and 2 years after 1971, i.e. 1972 and 1973. According to the mechanism, there should not be any impact in the crime rate prior to the year of birth and also no effect in years after the birth, but a significant impact either in the year of birth or 1 year after the birth or both. To present this analysis, I run the following regression:

$$Crime_{c,t,a} = \rho_0 + \sum_{n=-2}^{2} \rho_1 TSP_{c,t-a-n}\, \rho_2 X_{c,t} + \gamma_c + \theta_{t-a} + \mu_a + \epsilon_{c,t} \quad (4)$$

Where $TSP_{c,t-a-n}$ gives the amount of pollution in birth year and 2 years prior and 2 after the birth year for age group *a.* Then I plot out the distribution of these effects by plotting the estimates on the pollution (TSP) variable along with their 90 percent confidence intervals. Figure 3 shows the impact of these leads and lags of the pollution year with respect to the pollution in the birth on the property

[17] I also did a same event study analysis for different groups of ages and got similar results.
[18] I do a similar estimation for the violent crime rates and see insignificant impact for the cohorts before as well as after the implementation of act, which is consistent with our earlier results.

and violent crime rate. We see that the impact on property crime is significant at the time birth and also 1 year after the birth (early childhood), thus showing that the effects of TSP exposure are through early stages of life (either in the year of birth or early childhood). I do not see this impact on the violent crime rate in Panel B of Figure 3, which is consistent with our earlier results.

B. Migration

Since I am using the county level data, I assumed that a person is staying in the same county even 15-24 years after his/her birth, which might not be true in all the cases. People can migrate to other place due to various reasons like college education or employment opportunity, etc. Also, there could be some people who decided to move out of a particular county because that county was assigned the nonattainment status, and people might not want to live in more polluted counties. To address this issue, I employed the following strategy:

Migration Share in the States - Lower and Upper Bounds

I used the current state and the birth state from the 1980 census data to calculate the share of people in a particular state not born in that state itself, which will give me the share of people migrating into that state during the years after the implementation of the 1970 CAAA. Using the migration share of the states, I divided the states in two categories: one with states having higher share of migration, and the other with states having lower migration.[19] Then, I run separate regressions for each category, showing how the CAAA implementation affected the crime rates in states with lower migration share vs. states with higher migration share. This analysis can only be done at the state level and not at the county level because though the current county of residence is given in the census but for the birthplace, they only provide the state and not the county. Table 4 and 5 show the impact on the crime

[19] To divide the states in these two categories, I took the median share of the states and then, did the lower half and upper half to get the states with lower share of migration and higher share of migration, respectively.

rates for the states with lower migration share and the ones with higher migration share, respectively. As expected, the effect on property crime and larceny in the lower migration share states (Columns 1 and 3 of Table 4) is highly significant, with magnitudes being similar to the results of my baseline model. However, no significant impact can be seen on the crime rates of the higher migration share states (Table 5), which would imply that my results are not driven by the exposure in-utero or during early childhood of the cohorts born in different states but residing in another state 15-24 years later.

C. Controlling for past and current Industrial Composition

Now, one might argue that according to the 1970 Act, if a county is in nonattainment category, it will be forced to reduce pollution, and this will affect the industrial structure in that county currently as well as in the future. Thus, this change in industrial composition would have a direct impact on crime rate independent of its effect of pollution because the act might have permanently changed the industrial structure after its implementation.

So, to address this concern, I add a control variable for the industrial composition (in terms of employment ratio of various industries) for the years pollution is being observed (past industrial composition) and also for the years crime is being observed (future industrial composition) in my analysis. This will account for the changes in the industrial structure during the time of the birth as well as during adulthood. Table 6 presents the results after adding the control variable for the industrial composition during adulthood (in the years crime is being observed) as well as at the time of birth (years pollution is being observed). In the appendix, Table A2 shows the results after the control variable for only the industrial composition during adulthood and Table A3, that for only the industrial composition during the time of birth. I observe that there is no impact on any of the original results due to any change in the industrial structure caused by the reduction of pollution due to the 1970 CAAA. In all the tables, the significance level and the elasticities for the property crime and

larceny are still the same. Thus, my results are robust to any changes in the past or future industrial composition.

D. Agencies with Full Reporting

The UCR data that I am using for arrest rates, has well-known difficulties pertaining to agencies not being required to report statistics and with agencies being added to or dropped from counties from year to year. But UCR does provide information on which agencies reported statistics for all 12 months in a particular year. So, to correct for this issue, as a robustness check, I rerun my main specification (equation (1)) using only agencies with full reporting and dropping counties with irregular reporting.

Table 7 show the impact of the 1970 CAAA on crime when considering only those agencies which report the crime statistics for all 12 months in a year. It is clear from the results that my estimates were not impacted by putting a restriction on type of agencies based on the reporting criteria. In fact, my results were slightly improved. Column (1) of Panel B shows that the property crime rate is decreasing by 124 per 100,000 individuals for the nonattainment counties after the implementation of the 1970 act, which is significant at 5 percent level. Relative to the mean of 1,915 per 100,000 population for property crime, these results indicate that the CAAA reduced the property crime rates significantly, 15-24 years later in nonattainment counties by about 6 percent. Column (3) provides evidence that change in property rate is mainly coming from the decline in the larceny (decreasing by 109 per 100,000 individuals, which is significant at 1 percent level). Relative to the mean of 1,365 per 100,000 population for larceny, it decreased by approximately 8 percent. These reduced form estimates suggest that a 1 percent decrease in pollution (TSPs) at the time of birth, reduces property crime rates by 0.4 percent and larceny by 0.6 percent in the future.

E. Dropping Certain Controls

It could also seem that controlling for lagged prisoners per capita and lagged officers per capita might soak up a lot of variation in crime. Thus, as a robustness check I drop these variables to check if my results are driven by these controls. Dropping these controls would imply an exogeneity of the policy change.

Table 8 provides the reduced form estimates after dropping the lagged prisoners and lagged officers controls. The estimates provide evidence that my results are not driven by these controls as there is no significant change in my original results after dropping these controls.

F. Extension

Instrumental Variables Model

In-utero or early childhood exposure to pollution can possibly be correlated with observed as well as unobserved determinants of future criminal activities. It is possible that the implementation of CAAA impacted crime not only through its influence on pollution, but in ways other than pollution like the changes in the industrial composition or its effect on future pollution as well. However, I show that my results are robust to any changes in the industrial composition as well as changes in the future pollution level. Thus, as an extension to my model, I use the interaction term, $(Nonattainment_{c,1970} * 1[\tau > 1971])$, in equation (2) as an instrument in the two-staged least squares (2SLS) estimation strategy to investigate the impact of exposure to pollution at the time of birth on the future crime rates, using the following regression equation:

$$y_{c,t,a} = \sigma_0 + \sigma_1 TSP_{c,t-a} + \sigma_2 X_{c,t} + \gamma_c + \theta_t + \mu_a + \epsilon_{c,t} \quad (5)$$

Where the future property and violent crime rates of counties are regressed on the TSPs concentration of those counties at the time of the birth (for the years 1967-1975) for the cohorts who are 15-24 years old over the period of 1982-1999.

OLS Results: Table 9 show the OLS estimates of the effects of childhood exposure to pollution on criminal activities, presented by equation (5). Panel A presents the results of the violent crime rates and Panel B, that the property crimes. Column 1 reports the violent and property crime rates as a whole and column 2-5 shows the estimated coefficients on murder, rape, robbery and assault, respectively in Panel A. Columns 2-4 show the estimates for burglary, larceny and vehicle theft, respectively in Panel B. All the crime rates in the analysis are calculated per 100,000 individuals. The estimates of Panel A suggest that impact of pollution on the violent crime rates is insignificant. However, the point estimates of Panel B show that if TSP increases by 1 $\mu g/m^3$, then property crime will increase by 1.41 per 100,000 individuals, and this is significant at the 5 percent level. Relative to the mean value of 1,990 per 100,000 individuals for the property crime rates, a 1 percent change in TSP results in 0.1 percent increase in the property crime rates.

Second-Stage Results: Implementing the instrumental variables estimation strategy, Table 10 presents 2SLS estimates of the effects of exposure to pollution in the year of birth on future violent and property crime rates by exploiting the variation caused by 1970 CAAA. Column 1 in Table 10 provides a strong evidence of a positive and significant relation between the property crime rate and the mean TSPs concentration. One $\mu g/m^3$ increase in TSP will increase the property crime by 6 per 100,000 individuals, amounting to 0.3 percent increase, relative to its mean of around 1,990 per 100,000 individuals. This significant change in property crime is mainly coming from larceny. Relative to its mean (1419 per 100,000 individuals), one percent increase in TSPs increases larceny by 0.4 percent, which is consistent with my reduced form difference-in-differences estimates. But

the coefficients on the violent crimes are not significantly different from zero. Thus, I mostly see the effect of exposure to pollution at the time of birth on the property crime than on the violent crime at county-level.

Regression Discontinuity Design (RDD)

Recall that the nonattainment status of the counties is assigned based on the TSP level of 75 μg/m^3 threshold.[20] The counties just above this threshold or cut-off point were assigned the nonattainment status and the ones right below this cut-off were designated as attainment counties. Thus, exploiting this discontinuity in the nonattainment status caused by the threshold, I use RDD to compare the cohorts born in counties that were just above and below this cut-off to estimate the treatment effect of being assigned as the nonattainment area. To estimate the RDD model, I run the following local linear regression equation:

$$y_{c,t,a} = \beta_0 + \beta_1(Nonattainment_{c,1970} * Post1971) + \beta_2(Nonattainment_{c,1970} * RV_{c,1970}) + \beta_3 X_{c,t} + \gamma_c + \theta_t + \mu_a + \epsilon_{a,c,t} \quad (6)$$

Here, $RV_{c,1970}$ is the running variable, which is constructed by normalizing the TSP level by the threshold set at the 1970 county pollution level. The running variable is set to zero for the cohorts born before 1972, the treatment year. Using the *RV,* Figure 4 plots the jump in the probability of receiving the nonattainment status (treatment) from 0 to 1 at the cut-off, showing a sharp RD design for our model. Table 11 presents the results obtained from estimating equation (6). Panel A shows the estimates of the RDD model for the outcome, mean TSP concentration and Panel B and Panel C, respectively, present the estimates for the effect of the nonattainment status on the property crime rate and larceny. Columns 1, 2 and 3 represents the three different bandwidths of 25 μg/m^3, 50

[20] Though the nonattainment status was assigned based on two thresholds, the second threshold of second-highest daily reading of the year was not binding. Also, there were very few counties out of a total of 297 who satisfied second condition and not the first one. Therefore, following Isen et al. (2017), I use only the first condition to determine the cut-off point for the RDD model.

$\mu g/m^3$, and 75 $\mu g/m^3$ surrounding the cut-off point. Most of the results in all three panels are highly significant with an exception of the property crime and larceny at bandwidth of 25 $\mu g/m^3$. The magnitude of these reduced form estimates suggests that a 1 percent decrease in TSP exposure, decreases the property crime by 0.5 percent and larceny by 0.6 percent, which are quite similar to the results of my baseline model. Though, the reduced form results of the RDD model are similar in magnitude with the results of the difference-in-differences model, it is still sensitive at lower bandwidth. This could be due to the fact that the running variable has a lower density and that the small number of counties in the sample is resulting in even fewer counties at the cut-off point, which makes it difficult to accurately predict the estimates. These conclusions for the RDD model are consistent with the results obtained by other papers using the RD design for the 1970 CAAA (Sanders and Stoecker, 2015; and Isen et al., 2017).

To validate the RD design, mainly two assumptions are made: (a) the other county characteristics are all similar on either side of the cut-off of the running variable; and (b) the counties cannot manipulate their TSP levels before the CAAA implementation to possibly escape from getting the nonattainment status. Following Imbens and Lemieux (2008), I validate the first assumption by conducting balancing tests to check for any discontinuity in the county characteristics at the threshold of the running variable and find that they are not significantly different at the threshold. And, in support of the second assumption I perform a density test to check that there is no heaping of the running variable at the threshold (McCrary, 2008). The results obtained with different bandwidths show that the density of the running variable obtained from the TSP level, is smooth around the threshold, suggesting that there was no manipulation of the values.

VIII. CONCLUSION

In this paper, I empirically analyze the impact of 1970 Clean Air Act Amendment on future adult criminal activities using a difference-in-differences estimation strategy. I use the variations in TSPs concentration (level of air pollution) caused by the 1970 Clean Air Act Amendment to distinguish and thus, compare the cohorts born before and after the implementation of the act, in the nonattainment counties (treatment group) with the cohorts born in attainment counties (control group).

I find that there was a significant reduction in the pollution level of the nonattainment counties due to the 1970 CAAA, which consequently had a significant negative impact on the crime rate, in adulthood, after 15-24 years. In this paper, I find that CAAA reduced pollution level by 14 percent and the property crime and larceny rates by 4 percent and 5 percent, respectively, of the nonattainment counties in comparison to the attainment counties. Together, these reduced form estimates suggest that a 1 percent decrease in TSP exposure, decreases the property crime by 0.3 percent and larceny by 0.4 percent, which is consistent with estimates in the prior literature. There is no evidence of the impact of the 1970 CAAA on violent crime. My results are consistent with figure 1, i.e. they show that there is a significant impact of early exposure to pollution on property crime as compared to violent crime after 15-24 years. These results provide evidence that effect of 1970 CAAA on future criminal activities could also be one of the explanations for a sudden decline in crime rates in 1990s. Also, all of my results are very robust to any changes in industrial composition, changes in the future pollution or the migration of people from one state to another, thus, showing that in-utero and early childhood exposure to pollution were significant determinants of future crimes and not the pollution in later years.

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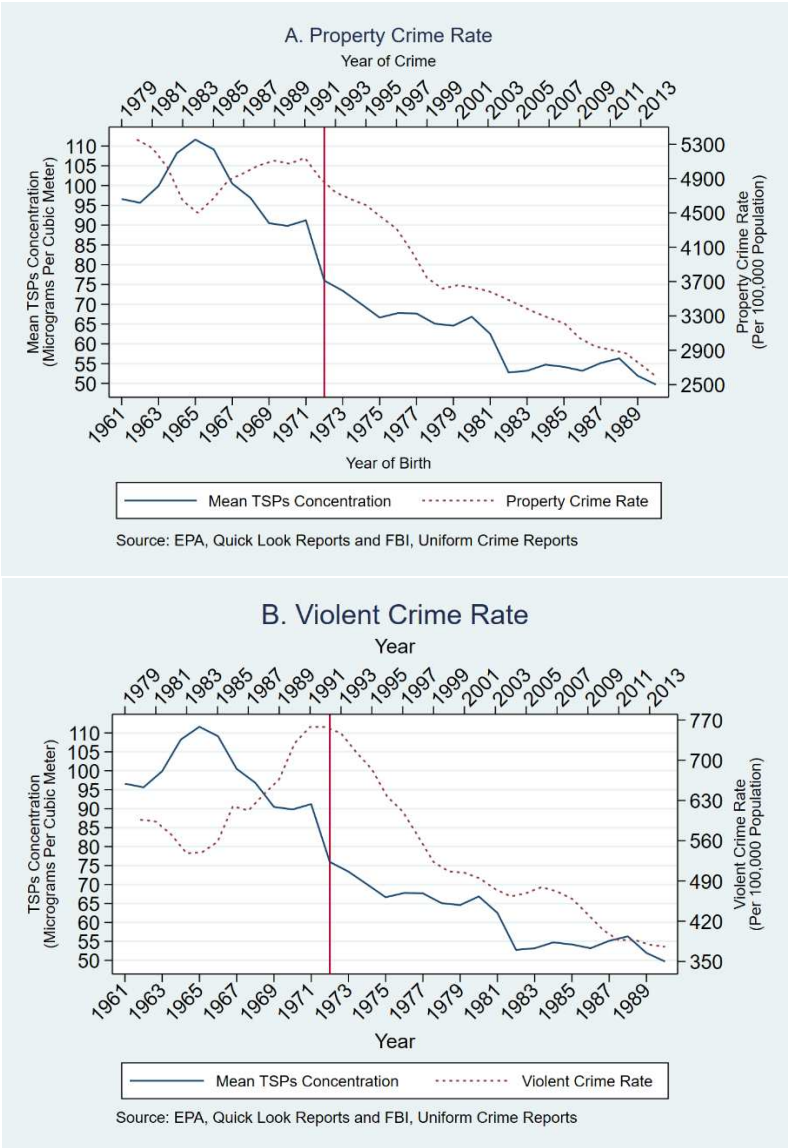
LIST OF FIGURES AND TABLES

FIGURE 1

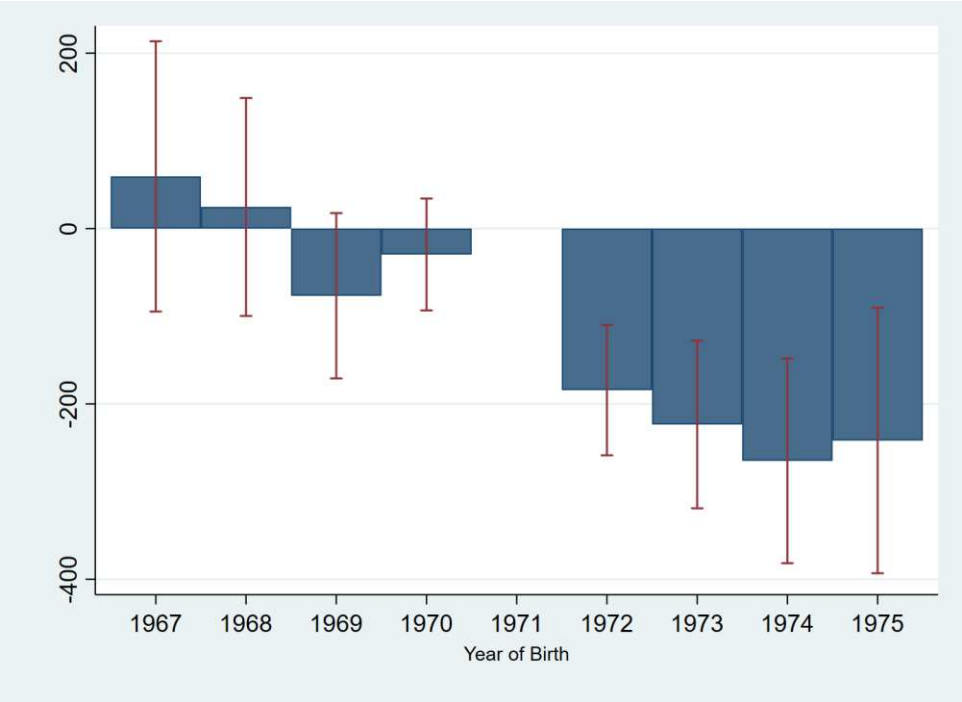
National Trends in TSP Air Pollution and Violent and Property Crime Rates



Notes: The annual national trends in average total suspended particulates (TSPs), a measure of air pollution from 1961-1990 in the US, are on the left-hand side axis of both panels, and the annual rates of Violent and Property Crime from 1979-2014 for the US, are on the right-hand side axis of Panel A and Panel B, respectively. In both the panels, the above horizontal axis gives the Years of Crime and the below horizontal axis gives the Years of Birth of cohorts of ages 15-24 years old. The figure shows that the pollution trends at the time of birth matches one-to-one with the crime rates 15-24 years later. For example, the crime rate in 1987 for an 18 years old cohort matches with the pollution level at the time of their birth in 1969.

FIGURE 2

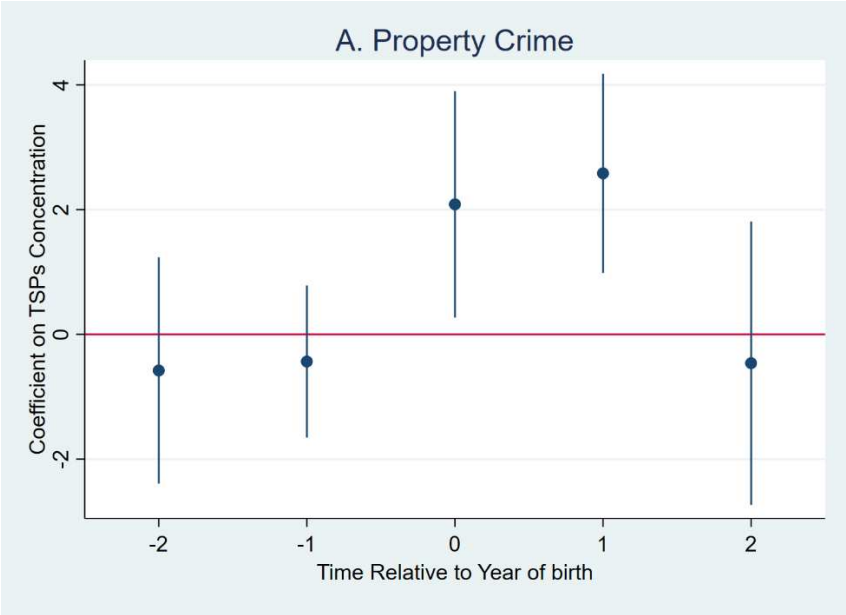
Event Study Analysis for Property Crime

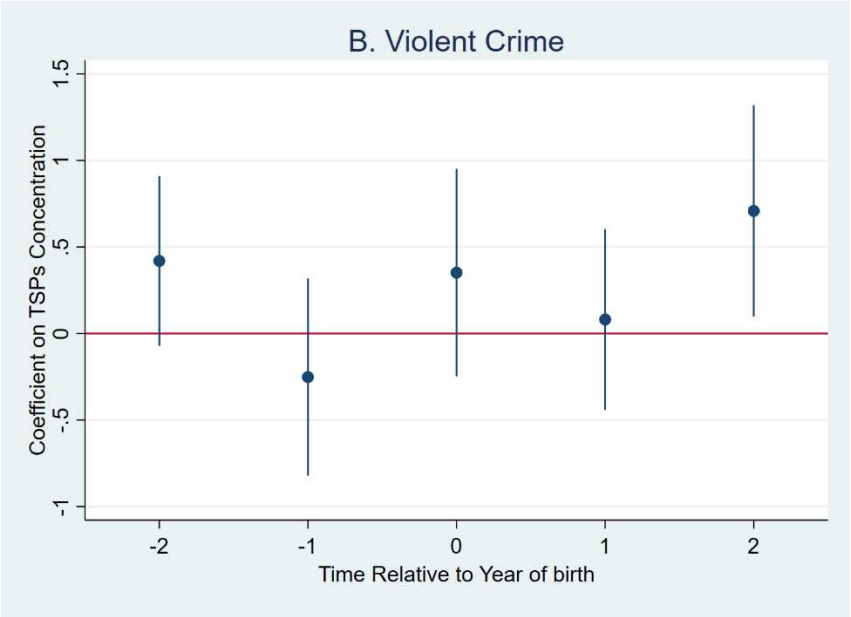


Notes: To produce the figure, I estimated the following regression: $Property\ Crime_{c,t,a} = \delta_0 + \sum_{y=1967}^{1975} \delta_1 (Non_{c,t-a} * 1[Year_{t-a} = y]) + \delta_2 X_{c,t} + \gamma_c + \theta_{t-a} + \mu_a + \epsilon_{c,t}$, where $Property\ Crime_{c,t,a}$ is the property crime rate per 100,000 population in county *c* in year *t* for 15-24 years old cohorts separately. $Non_{c,t-a}$ takes a value of 1 if the county has been assigned nonattainment status in the year 1970. $1[Year_{t-a} = y]$ are the dummies for the pollution years. The bars present the point estimates of the interaction of the year dummies with nonattainment status of the county. The lines are 95 percent confidence intervals. The omitted year is 1971 because the act was implemented in 1972.

FIGURE 3

Robustness Check for the effect of Leads and Lags of Pollution relative to Birth Year Pollution

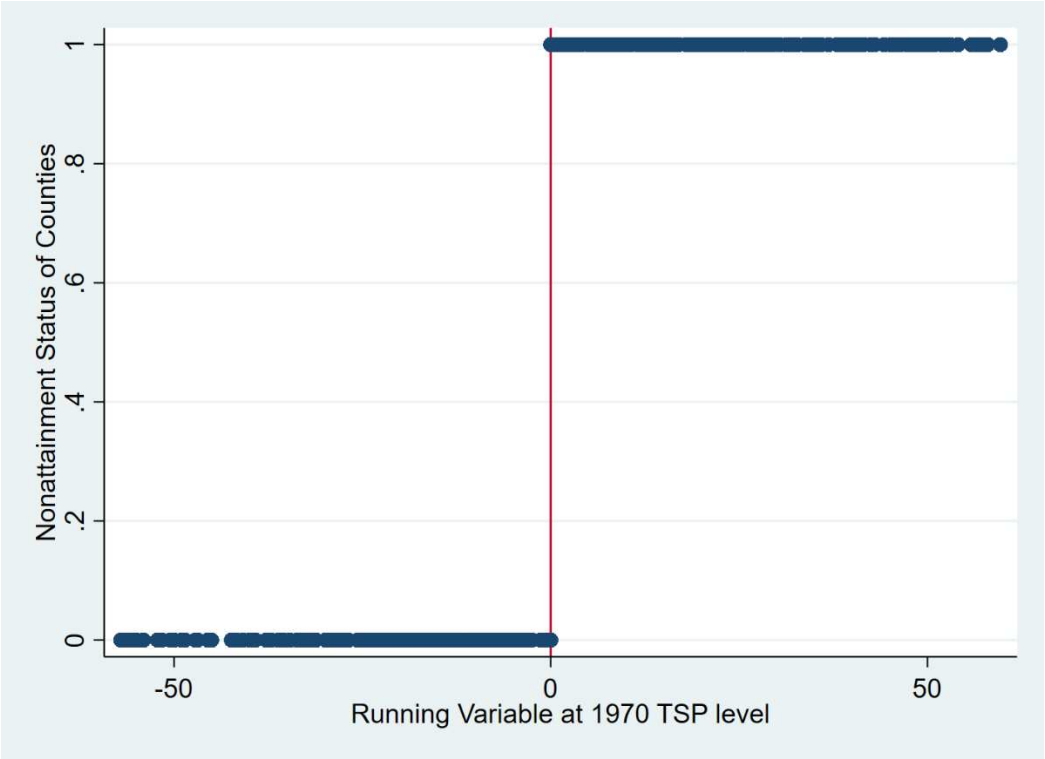




Notes: To produce the figure, I estimated the following regression: $Crime_{c,t,a} = \rho_0 + \sum_{n=-2}^{2} \rho_1 TSP_{c,t-a-n}\, \rho_2 X_{c,t} + \gamma_c + \theta_{t-a} + \mu_a + \epsilon_{c,t}$, where $Crime_{c,t,a}$ is the property and violent crime rate per 100,000 population in county c in year t. $TSP_{c,t-a-n}$ gives the amount of pollution in birth year and 2 years prior and 2 after the birth year for age group a. The dots present the point estimates of the pollution years. The lines are 90 percent confidence intervals.

FIGURE 4

Jump of the Treatment Variable (Nonattainment Status) at the Running Variable's Cut-off



Notes: The Figure represents the case of sharp RD design, where probability of the treatment variable (nonattainment status) goes from zero to one at the threshold of the running variable.

Table 1: Summary Statistics for Attainment and Nonattainment Counties

	(1)	(2)	(3)	(4)	(5)	(6)
	Whole Sample (N=22,511)		Attainment (N=10,730)		Nonattainment (N=11,781)	
VARIABLES	Mean	Std. Dev	Mean	Std. Dev.	Mean	Std. Dev.
Violent Crime per 100,0000 Population	580.6	582.0	519.9	576.6	638.5	581.3
Murder per 100,0000 Population	20.01	57.00	17.93	60.22	22.00	53.69
Rape per 100,0000 Population	35.94	95.27	36.62	114.5	35.29	72.33
Robbery per 100,0000 Population	112.9	165.1	89.19	148.5	135.5	176.6
Assault per 100,0000 Population	411.8	467.8	376.1	474.0	445.8	459.3
Property Crime per 100,0000 Population	1,981	1,467	2,051	1,540	1,915	1,390
Burglary per 100,0000 Population	439.4	519.5	470.7	573.1	409.5	460.7
Larceny per 100,0000 Population	1,403	1,064	1,444	1,103	1,365	1,024
Vehicle Theft per 100,0000 Population	138.6	225.8	136.3	224.0	140.9	227.4
Average Annual TSP Concentration	72.85	30.34	56.07	17.10	88.86	31.55
Police per 1000 population	2.242	0.588	2.260	0.607	2.226	0.569
Prisoners per 100,000 population	316.0	113.4	311.6	116.9	320.1	109.7
Poverty Rate	14.06	3.560	14.30	3.511	13.82	3.591
% Black	9.060	11.67	7.432	11.02	10.61	12.05
Income Per Capita	23,957	6,030	22,894	5,265	24,971	6,520
Total Employment	161,778	297,483	91,140	148,639	229,201	377,600
Total Transfer Receipts Per Capita	7,132	1,693	7,094	1,604	7,168	1,773
Average Annual Precipitation	3.249	1.395	3.229	1.308	3.267	1.472
Average Annual Temperature	52.86	9.158	52.35	8.723	53.34	9.530

Table 2: Estimates for the Effect of CAAA Implementation on Pollution Level (TSPs)

	Mean TSPs Concentration
Nonattainment Status × Post1971	**-13.809*** **
	(1.72)
% Black	0.189
	(0.49)
Poverty Rate	0.006
	(0.10)
Income Per Capita	-0.000
	(0.00)
Total Transfer Receipts Per Capita	-0.001
	(0.00)
Total Employment	0.000
	(0.00)
Average Annual Precipitation	-1.583
	(1.06)
Average Annual Temperature	-0.201
	(0.62)
Year of Birth Weather Controls	Yes
County Characteristics	Yes
County FEs	Yes
Year FEs	Yes
Observations	3,233

Notes: This table reports the first stage regressions results to show the relationship between nonattainment status of the counties and the TSPs concentration in those counties after the 1970 CAAA implementation. It includes the year of birth weather controls like average annual precipitation and temperature and also controls for county characteristics like % black, income per capita, unemployment rate, poverty rate, prisoners per capita, and police per capita. Standard errors are in parentheses and clustered at county level.
* p<0.1 ** p<0.05 *** p<0.01

Table 3: Reduced Form estimates for The Effect of CAAA Implementation on Violent and Property Crimes

	(1)	(2)	(3)	(4)	(5)
Panel A: Violent Crimes Per 100,000 Individuals					
	Violent Crime	Murder	Rape	Robbery	Assault
Nonattainment Status × Post1971	13.343	0.186	0.316	1.927	10.914
	(13.87)	(1.33)	(2.13)	(3.78)	(11.87)
Panel B: Property Crimes Per 100,000 Individuals					
	Property Crime	Burglary	Larceny	Vehicle Theft	
Nonattainment Status × Post1971	**-88.086****	-23.475	**-76.981****	12.369	
	(41.52)	(15.10)	(30.85)	(8.09)	
Year of Birth Weather Controls	Yes	Yes	Yes	Yes	Yes
County Characteristics	Yes	Yes	Yes	Yes	Yes
Age FEs	Yes	Yes	Yes	Yes	Yes
County FEs	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes
Observations	22,511	22,511	22,511	22,511	22,511

Notes: This table reports the reduced form regressions coefficients for the effect of average annual TSP exposure at the time of birth on criminal activities 15-24 years later due to the variation cause by 1970 CAAA. It includes the year of birth weather controls like average annual precipitation and temperature and also controls for county characteristics like % black, income per capita, total employment, transfer receipts per capita, poverty rate, prisoners per capita, and police per capita. Standard errors are in parentheses and clustered at county level.
* p<0.1 ** p<0.05 *** p<0.01

Table 4: Reduced Form estimates for The Effect of CAAA Implementation on Violent and Property Crimes (For States with Lower Migration Share)

	(1)	(2)	(3)	(4)	(5)
Panel A: Violent Crimes Per 100,000 Individuals					
	Violent Crime	Murder	Rape	Robbery	Assault
Nonattainment Status × Post1971	1.719	2.547	-2.600	5.585	-3.813
	(20.14)	(1.84)	(4.01)	(4.44)	(18.25)
Panel B: Property Crimes Per 100,000 Individuals					
	Property Crime	Burglary	Larceny	Vehicle Theft	
Nonattainment Status × Post1971	**-81.409****	-19.477	**-64.785****	2.852	
	(34.98)	(14.60)	(25.94)	(6.01)	
Year of Birth Weather Controls	Yes	Yes	Yes	Yes	Yes
County Characteristics	Yes	Yes	Yes	Yes	Yes
Age FEs	Yes	Yes	Yes	Yes	Yes
County FEs	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes
Observations	11,950	11,950	11,950	11,950	11,950

Notes: This table reports the reduced form regressions coefficients for the effect of average annual TSP exposure at the time of birth on criminal activities 15-24 years later due to the variation cause by 1970 CAAA. It includes the year of birth weather controls like average annual precipitation and temperature and also controls for county characteristics like % black, income per capita, total employment, transfer receipts per capita, poverty rate, prisoners per capita, and police per capita. Standard errors are in parentheses and clustered at county level. It includes only those states which had lower migration share from the year 1970-1980.
* p<0.1 ** p<0.05 *** p<0.01

Table 5: Reduced Form estimates for The Effect of CAAA Implementation on Violent and Property Crimes (For States with Higher Migration Share)

	(1)	(2)	(3)	(4)	(5)
Panel A: Violent Crimes Per 100,000 Individuals					
	Violent Crime	Murder	Rape	Robbery	Assault
Nonattainment Status × Post1971	66.539	2.661	10.601	4.538	48.739
	(37.93)	(4.35)	(7.37)	(12.67)	(37.09)
Panel B: Property Crimes Per 100,000 Individuals					
	Property Crime	Burglary	Larceny	Vehicle Theft	
Nonattainment Status × Post1971	-46.989	-15.291	-27.796	-3.902	
	(98.10)	(30.31)	(79.34)	(17.17)	
Year of Birth Weather Controls	Yes	Yes	Yes	Yes	Yes
County Characteristics	Yes	Yes	Yes	Yes	Yes
Age FEs	Yes	Yes	Yes	Yes	Yes
County FEs	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes
Observations	10,561	10,561	10,561	10,561	10,561

Notes: This table reports the reduced form regressions coefficients for the effect of average annual TSP exposure at the time of birth on criminal activities 15-24 years later due to the variation cause by 1970 CAAA. It includes the year of birth weather controls like average annual precipitation and temperature and also controls for county characteristics like % black, income per capita, total employment, transfer receipts per capita, poverty rate, prisoners per capita, and police per capita. Standard errors are in parentheses and clustered at county level. It includes only those states which had higher migration share from the year 1970-1980.
* p<0.1 ** p<0.05 *** p<0.01

Table 6: Reduced Form estimates for The Effect of CAAA Implementation on Violent and Property Crimes (controlling for both past and future industrial composition)

	(1)	(2)	(3)	(4)	(5)
Panel A: Violent Crimes Per 100,000 Individuals					
	Violent Crime	Murder	Rape	Robbery	Assault
Nonattainment Status × Post1971	10.508	0.552	0.815	-0.901	10.042
	(13.38)	(1.44)	(2.48)	(3.56)	(11.35)
Panel B: Property Crimes Per 100,000 Individuals					
	Property Crime	Burglary	Larceny	Vehicle Theft	
Nonattainment Status × Post1971	**-75.396***	-9.962	**-70.964****	5.530	
	(42.07)	(15.65)	(30.67)	(7.59)	
Year of Birth Weather Controls	Yes	Yes	Yes	Yes	Yes
County Characteristics	Yes	Yes	Yes	Yes	Yes
Age FEs	Yes	Yes	Yes	Yes	Yes
County FEs	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes
Observations	19,385	19,385	19,385	19,385	19,385

Notes: This table reports the reduced form regressions coefficients for the effect of average annual TSP exposure at the time of birth on criminal activities 15-24 years later due to the variation cause by 1970 CAAA. It includes the year of birth weather controls like average annual precipitation and temperature and also controls for county characteristics like % black, income per capita, total employment, transfer receipts per capita, poverty rate, prisoners per capita, and police per capita. Standard errors are in parentheses and clustered at county level. It includes the industrial composition in the both crime years as well as pollution years.

* p<0.1 ** p<0.05 *** p<0.01

Table 7: Reduced Form estimates for The Effect of CAAA Implementation on Violent and Property Crimes (Only using Agencies with Full Reporting)

	(1)	(2)	(3)	(4)	(5)
Panel A: Violent Crimes Per 100,000 Individuals					
	Violent Crime	Murder	Rape	Robbery	Assault
Nonattainment Status × Post1971	10.133	-0.625	-0.160	2.579	8.339
	(14.42)	(1.19)	(1.64)	(3.92)	(11.74)
Panel B: Property Crimes Per 100,000 Individuals					
	Property Crime	Burglary	Larceny	Vehicle Theft	
Nonattainment Status × Post1971	**-123.850*****	**-25.712***	**-109.601*****	11.463	
	(44.76)	(13.73)	(34.04)	(8.04)	
Year of Birth Weather Controls	Yes	Yes	Yes	Yes	Yes
County Characteristics	Yes	Yes	Yes	Yes	Yes
Age FEs	Yes	Yes	Yes	Yes	Yes
County FEs	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes
Observations	19,292	19,292	19,292	19,292	19,292

Notes: This table reports the reduced form regressions coefficients for the effect of average annual TSP exposure at the time of birth on criminal activities 15-24 years later due to the variation cause by 1970 CAAA. It includes the year of birth weather controls like average annual precipitation and temperature and also controls for county characteristics like % black, income per capita, total employment, transfer receipts per capita, poverty rate, prisoners per capita, and police per capita. Standard errors are in parentheses and clustered at county level.
* p<0.1 ** p<0.05 *** p<0.01

Table 8: Reduced Form estimates for The Effect of CAAA Implementation on Violent and Property Crimes (Without Lagged Prisoners and Lagged Officers)

	(1)	(2)	(3)	(4)	(5)
Panel A: Violent Crimes Per 100,000 Individuals					
	Violent Crime	Murder	Rape	Robbery	Assault
Nonattainment Status × Post1971	13.448	0.208	0.188	1.971	11.081
	(13.94)	(1.32)	(2.09)	(3.77)	(11.89)
Panel B: Property Crimes Per 100,000 Individuals					
	Property Crime	Burglary	Larceny	Vehicle Theft	
Nonattainment Status × Post1971	**-79.450***	-23.297	**-69.153****	13.000	
	(40.46)	(14.93)	(29.72)	(8.06)	
Year of Birth Weather Controls	Yes	Yes	Yes	Yes	Yes
County Characteristics	Yes	Yes	Yes	Yes	Yes
Age FEs	Yes	Yes	Yes	Yes	Yes
County FEs	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes
Observations	22,511	22,511	22,511	22,511	22,511

Notes: This table reports the reduced form regressions coefficients for the effect of average annual TSP exposure at the time of birth on criminal activities 15-24 years later due to the variation cause by 1970 CAAA. It includes the year of birth weather controls like average annual precipitation and temperature and also controls for county characteristics like % black, income per capita, total employment, transfer receipts per capita, poverty rate, prisoners per capita, and police per capita. Standard errors are in parentheses and clustered at county level.
* p<0.1 ** p<0.05 *** p<0.01

Table 9: OLS estimates for The Effect of Mean TSPs on Violent and Property Crimes - For 1970 CAAA

	(1)	(2)	(3)	(4)	(5)
Panel A: Violent Crimes Per 100,000 Individuals					
	Violent Crime	Murder	Rape	Robbery	Assault
Mean TSPs	-0.120	0.009	0.005	-0.044	-0.089
	(0.10)	(0.01)	(0.01)	(0.04)	(0.09)
Panel B: Property Crimes Per 100,000 Individuals					
	Property Crime	Burglary	Larceny	Vehicle Theft	
Mean TSPs	**0.861****	**0.356****	**0.525****	-0.020	
	(0.38)	(0.17)	(0.23)	(0.06)	
Year of Birth Weather Controls	Yes	Yes	Yes	Yes	Yes
County Characteristics	Yes	Yes	Yes	Yes	Yes
Age FEs	Yes	Yes	Yes	Yes	Yes
County FEs	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes
Observations	22,511	22,511	22,511	22,511	22,511

Notes: Regressions are the effects of average annual TSP exposure at the time of birth on criminal activities 15-24 years later exploiting the variation caused by 1970 Clean Air Act. It includes the year of birth weather controls like average annual precipitation and temperature and also controls for county characteristics like % black, income per capita, total employment, transfer receipts per capita, poverty rate, prisoners per capita, and police per capita. Standard errors are in parentheses and clustered at county level.
* p<0.1 ** p<0.05 *** p<0.01

Table 10: 2SLS estimates for The Effect of Mean TSPs on Violent and Property Crimes - For 1970 CAAA

	(1)	(2)	(3)	(4)	(5)
Panel A: Violent Crimes Per 100,000 Individuals					
	Violent Crime	Murder	Rape	Robbery	Assault
Mean TSPs	-0.814	-0.011	-0.019	-0.118	-0.666
	(0.84)	(0.08)	(0.13)	(0.23)	(0.72)
Panel B: Property Crimes Per 100,000 Individuals					
	Property Crime	Burglary	Larceny	Vehicle Theft	
Mean TSPs	**5.376****	1.433	**4.698****	-0.755	
	(2.61)	(0.92)	(1.98)	(0.49)	
Year of Birth Weather Controls	Yes	Yes	Yes	Yes	Yes
County Characteristics	Yes	Yes	Yes	Yes	Yes
Age FEs	Yes	Yes	Yes	Yes	Yes
County FEs	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes
Observations	22,511	22,511	22,511	22,511	22,511

Notes: This table reports the second stage regressions coefficients for the effect of average annual TSP exposure at the time of birth on criminal activities 15-24 years later using the variation cause by 1970 CAAA. It includes the year of birth weather controls like average annual precipitation and temperature and also controls for county characteristics like % black, income per capita, total employment, transfer receipts per capita, poverty rate, prisoners per capita, and police per capita. Standard errors are in parentheses and clustered at county level.
* p<0.1 ** p<0.05 *** p<0.01

Table 11: The Effect of 1970 CAAA Implementation on TSP, Property Crime, and Larceny: Regression Discontinuity Design

	(1)	(2)	(3)
	BW - 25	BW - 50	BW - 75
Panel A: Mean TSPs Concentration			
Nonattainment Status × Post1971	-14.692***	-18.517***	-17.167***
	(5.07)	(4.03)	(3.62)
Panel B: Property Crimes Per 100,000 Individuals			
Nonattainment Status × Post1971	-161.758*	-189.540***	-168.270**
	(98.00)	(72.78)	(68.32)
Panel C: Larceny Per 100,000 Individuals			
Nonattainment Status × Post1971	-123.257	-174.555***	-161.827***
	(92.47)	(63.95)	(58.86)
Year of Birth Weather Controls	Yes	Yes	Yes
County Characteristics	Yes	Yes	Yes
Age FEs	Yes	Yes	Yes
County Fes	Yes	Yes	Yes
Year Fes	Yes	Yes	Yes
Observations	16,340	20,418	21,663

Notes: This table reports the estimates from the RDD model using 1970 TSP level of the counties for three different bandwidths: 25 $\mu g/m^3$, 50 $\mu g/m^3$, and 75 $\mu g/m^3$ in column 1, 2 and 3, respectively. The running variable is the 1970 county TSP level (normalized by the 75 $\mu g/m^3$ threshold) and is interacted with a dummy indicating the nonattainment status of the counties at 1970 TSP level. The running variable is set to zero for cohorts born before 1972, thus, the results in the table are the estimates of the effect of the nonattainment status on the criminal activities 15-24 years later of the cohorts born after 1972. It includes the year of birth weather controls like average annual precipitation and temperature and also controls for county characteristics like % black, income per capita, total employment, transfer receipts per capita, poverty rate, prisoners per capita, and police per capita. Standard errors are in parentheses and clustered at county level. * p<0.1 ** p<0.05 *** p<0.01

APPENDIX

Data Appendix

Prisoners

Data on prisoners per capita is at the state level obtained from the "National Prisoner Statistics" published by the Bureau of Justice Statistics.

Police

Police per capita is also at the state level, calculated using the "Police Employee (LEOKA) Data" provided by UCR program published by the FBI annually.

Poverty

Poverty rate data at the state level each year is taken from the Bureau of the Census "United States Statistical Abstract".

Employment and Unemployment

Unemployment rate at the county level is provided by the Bureau of Labor Statistics. And, employment levels at the county level by industries is taken by the Bureau of Economic Analysis to calculate the manufacturing employment ratio (the proxy for 1st instrument).

Income

Income per capita used is at the county level, which is from the Bureau of Economic Analysis.

Population

To calculate the crime rates, I have taken the population estimates for the United States at the county level by age and sex from the U.S. Census Bureau.

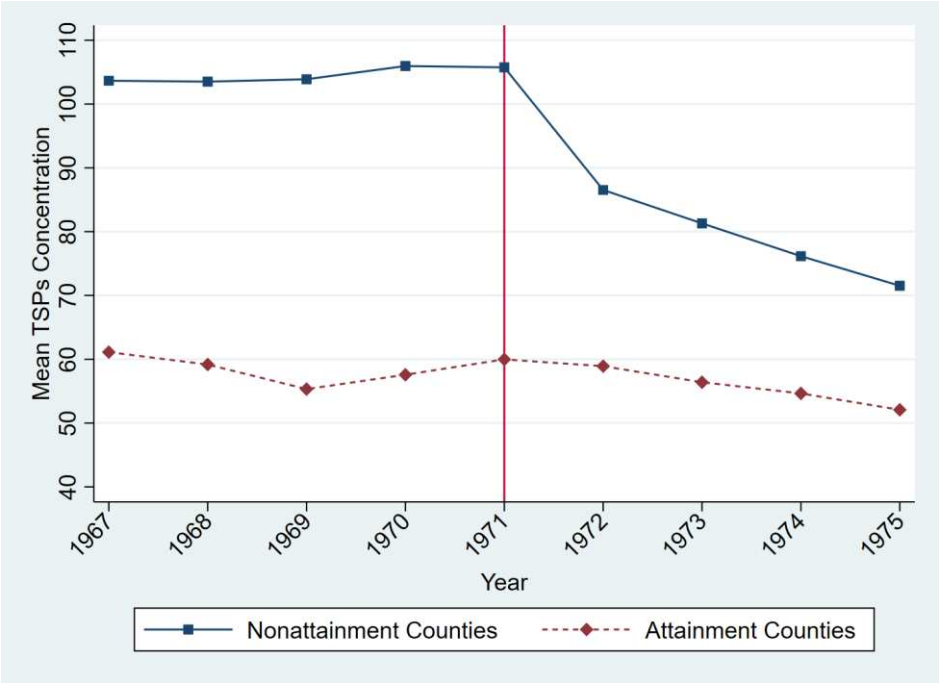
Precipitation and Temperature

The average annual precipitation and temperature at the county level is obtained from the "Climate Division" of the National Centers for Environmental Information.

Appendix Figures and Tables

FIGURE A1

National Trends in TSP Air Pollution in Nonattainment vs. Attainment Counties



Notes: The annual national trends in average total suspended particulates (TSPs), a measure of air pollution from 1967-1975 in the US, for nonattainment and attainment counties separately. It shows a significant drop in the TSP level of the attainment counties after the implementation of 1970 CAAA in the attainment counties as compared to the TSP level of attainment counties, which is fairly constant over the period.

Table A1: Key Dates Associated with the Clean Air Act Amendments of 1970

Date	Event
December 31, 1970	President Nixon Signs 1970 Clean Air Act Amendments
April 30, 1971	EPA Sets National Ambient Air Quality Standards. Must be Achieved by 1975, with possibility of a 2-Year Extension
August 14, 1971	EPA Publishes Requirements for Preparation, Adoption, and Submittal of State Implementation Plans in *Code of Federal Regulations*
January 1972	All State Implementation Plans Due to EPA

Source: Greenstone (2003b)

Table A2: Reduced Form estimates for The Effect of CAAA Implementation on Violent and Property Crimes (controlling for future industrial composition)

	(1)	(2)	(3)	(4)	(5)
Panel A: Violent Crimes Per 100,000 Individuals					
	Violent Crime	Murder	Rape	Robbery	Assault
Nonattainment Status × Post1971	4.890	2.530	-0.614	2.669	0.306
	(17.11)	(1.72)	(3.73)	(4.04)	(15.39)
Panel B: Property Crimes Per 100,000 Individuals					
	Property Crime	Burglary	Larceny	Vehicle Theft	
Nonattainment Status × Post1971	**-79.172****	-9.412	**-67.975****	-1.784	
	(34.76)	(14.29)	(26.38)	(6.21)	
Year of Birth Weather Controls	Yes	Yes	Yes	Yes	Yes
County Characteristics	Yes	Yes	Yes	Yes	Yes
County FEs	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes
Observations	19,385	19,385	19,385	19,385	19,385

Notes: This table reports the reduced form regressions coefficients for the effect of average annual TSP exposure at the time of birth on criminal activities 15-24 years later using the variation cause by 1970 CAAA. It includes the year of birth weather controls like average annual precipitation and temperature and also controls for county characteristics like % black, income per capita, total employment, transfer receipts per capita, poverty rate, prisoners per capita, and police per capita. Standard errors are in parentheses and clustered at county level. It also includes the industrial composition in the years crime is observed.

* p<0.1 ** p<0.05 *** p<0.01

Table A3: Reduced Form estimates for The Effect of CAAA Implementation on Violent and Property Crimes (controlling for past industrial composition)

	(1)	(2)	(3)	(4)	(5)
Panel A: Violent Crimes Per 100,000 Individuals					
	Violent Crime	Murder	Rape	Robbery	Assault
Nonattainment Status × Post1971	3.720	2.628	-0.548	2.726	-1.087
	(16.95)	(1.69)	(3.72)	(4.09)	(15.18)
Panel B: Property Crimes Per 100,000 Individuals					
	Property Crime	Burglary	Larceny	Vehicle Theft	
Nonattainment Status × Post1971	**-81.306****	-12.030	**-68.403*****	-0.874	
	(33.58)	(13.95)	(25.65)	(5.95)	
Year of Birth Weather Controls	Yes	Yes	Yes	Yes	Yes
County Characteristics	Yes	Yes	Yes	Yes	Yes
County FEs	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes
Observations	19,385	19,385	19,385	19,385	19,385

Notes: This table reports the reduced form regressions coefficients for the effect of average annual TSP exposure at the time of birth on criminal activities 15-24 years later using the variation cause by 1970 CAAA. It includes the year of birth weather controls like average annual precipitation and temperature and also controls for county characteristics like % black, income per capita, total employment, transfer receipts per capita, poverty rate, prisoners per capita, and police per capita. Standard errors are in parentheses and clustered at county level. It also includes the industrial composition in the years pollution is observed.

* p<0.1 ** p<0.05 *** p<0.01