Canary in a Coal Mine: Impact of Mid-20th Century Air Pollution Induced by Coal-Fired Power Generation on Infant Mortality and Property Values *

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Abstract

This paper studies the local impact of air pollution on infant mortality and housing prices. The empirical analysis relies on the historical expansion in fossil fuel electricity generation from 1938 to 1962, the leading source of domestic coal consumption by the mid-20th century. Combining newly digitized information on plant-level coal consumption with county-level air quality measures and infant mortality rates, we find that increases in coal consumption are associated with higher concentrations of total suspended particulates (TSPs) and increases in infant mortality. Our estimates suggest that the rise in power plant emissions was responsible for an additional 12,720 infant deaths over the sample period. We examine whether these health costs were capitalizated into housing values. Although estimates of the average marginal willingness to pay for clean air are close to zero, there appears to be significant heterogeneity in the housing market response. At low levels of baseline electricity access, thermal power plants are considered an amenity by local residents. As access to electricity expands, the pollution costs overwhelm the benefits of energy production, and the relationship between thermal emissions and housing prices reverses. These results highlight a challenge for current energy policy in the developing world: Given the longevity of electricity generation infrastructure, policymakers must take into account both current and future preferences for thermal power when making investment decisions.

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1 Introduction

The process of development is often characterized by an increase and subsequent decrease in pollution.[1] Since pollution is a common by-product of industrial activity, policymakers face a tradeoff between promoting economic development and protecting the health of the urban population. Given the substantial health costs associated with outdoor air pollution, which is responsible for 1.3 million premature deaths per year worldwide (WHO, 2009), it is essential to have a clear understanding of these tradeoffs.

These issues are particularly salient in the electricity industry. Electricity is considered a key contributor to economic development, however, electricity production often requires the burning of fossil fuels, and thermal power plants are a major source of outdoor air pollution. We examine the tradeoffs associated with thermal power generation during the mid-20th century US. This period witnessed a sharp increase in fossil fuel powered electricity. Between 1940 and 1960, total installed thermal capacity rose from 39,927 to 133,282 megawatts, compared to an increase of just 21,199 megawatts in hydroelectric capacity. During this same time period, the share of electric utilities in total domestic coal consumption rose from 12% to over 57%. Prior to the passage of the 1963 Clean Air Act, electric utilities were not required to mitigate emissions, and power plants were a major contributor to outdoor air pollution (EPA, 1998). We study several questions related to the production of thermal energy: 1) Did coal consumption by electric utilities have effects on local air quality 2) Did coal consumption by electric utilities have effects on health? 3) How did property owners tradeoff the costs of power plant emissions against the benefits of local energy production? 4) How did these tradeoffs evolve along the process of development?

To study the effects of thermal power plant emissions on air quality and health, we rely on newly digitized information on the timing of power plant openings and detailed annual plant-

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[1] The concept of the environmental Kuznets curve (EKC) emerged in the 1990s (see Grossman and Krueger, 1991). This view was advanced by the World Bank's World Development Report 1992 (IBRD, 1992), which claimed: "The view that greater economic activity inevitably hurts the environment is based on static assumptions about technology, tastes and environmental investments (p.38)." More recently, there has been debate over the empirical support for this hypothesis (see Stern, 2004, for a discussion).

level information on capacity, net generation, and coal consumption. This information is combined to construct a measure of local thermal plant emissions: annual coal consumption within 50-miles of each county-centroid.[2] These data are then linked to county-level air quality measures and infant mortality rates. The empirical analysis exploits geographical and temporal variation in power plant coal consumption. To address potential endogeneity in year-over-year coal consumption of existing plants, we also adopt a difference-in-differences strategy that relies on the openings of new power plant.

We find that coal consumption for electricity production had negative and statistically significant effects on air quality and infant mortality. Our estimates imply that a 100,000-ton increase in local coal consumption is associated with a 0.66 to 1.15 increase in TSP concentration. For infant mortality, our preferred estimates imply that a 1 standard deviation increase in local coal consumption is associated with a 3% increase in infant mortality. These results imply that increased coal consumption by electric utilities was responsible for an additional 12,720 infant deaths over the sample period. Combining these results, we calculate that a 1% increase in TSP concentration is associated with a 0.15 to 0.29 percent increase in infant mortality. Interestingly, these estimates are similar – albeit slightly smaller in magnitude – to results found for the 1980s (Chay and Greenstone, 2003). The difference in magnitudes is consistent with evidence that the relationship between TSP exposure and health is nonlinear, and that the impact of a marginal reduction in TSP levels is greater at lower initial pollution levels.

We estimate hedonic regressions to examine whether these health costs were capitalizated into housing values. Although estimates of the average marginal willingness to pay for clean air are close to zero, we uncover significant heterogeneity in the housing market response according to initial household electricity access. Local coal consumption has positive effects on housing prices at low household electrification rates and negative effects at high household electrification rates. Importantly, these results suggest that benefits of electricity may

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[2] This distance is chosen to correspond with engineering models of pollution transport (Seinfeld and Pandis, 2006), and the results are not sensitive to alternative choices.

diminish with economic development, as a greater fraction of the population gain access to electricity (see Stern, 2004, for a summary of empirical research on the environmental Kuznets curve (EKC)). The results also highlight a challenge for current energy policy in the developing world: Given the longevity of electricity generation infrastructure, policymakers must anticipate future preferences for thermal power when making energy investment decisions. Overall, the changes in thermal coal consumption between 1940 and 1960 imply losses of \$4.3 billion (in 2010 dollars) in home values. Our estimates imply that households were willing to forgo \$19.1 billion to avoid the pollution costs associated with thermal power generation. This valuation is lower than more recent estimates. For example, hedonic estimates for the 1980s places the cost of pollution at \$52.5 billion (Chay and Greenstone, 2005). Nevertheless, it is notable that the housing market appears to have responded to local emissions, given the health hazards associated with air pollution were not well understood.

This paper proceeds as follows: Section 2 discusses the history of electrification in the United States. Section 3 describes the data. Section 5 presents our empirical framework. Section 6 reports our findings. Finally, Section 7 concludes.

2 Historical Background

2.1 Electricity Generation and Pollution

Electricity generation rose substantially during the mid-20th century. Figure 1 displays electricity generation by electric utilities. Between 1938 and 1963, it rose from 113.8 billion kilowatt-hours to 916.8 billion kilowatt hours and installed capacity rose from 37,492 MW to 210,549 MW.[3] Most of the growth occurred as new bigger plants were built and older, smaller plants were take offline. In fact, despite the larger increases in capacity, the total number of electric utility plants actually fell from 3,903 in 1938 to 3,402 in 1963.[4]

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[3] United States Bureau of the Census (1975), Series S8.

[4] United States Bureau of the Census (1975), Series S53-54.

The majority of the growth was a result of expansions in thermal capacity. Coal-fired generation was 41 percent of total generation in 1938 and 54 percent in 1963. On the other hand, the share of hydroelectric fell from 39% in 1938 to 18% in 1963.[5] The large increases in thermal capacity did not occur uniformly throughout the country. Instead, they were driven by factors such as local demand for electricity, accessibility of coal for fuel, and the suitability of local topography for hydroelectric generation. Figure 2 displays the geographic pattern of this expansion in coal-fired capacity of for the period 1940 to 1960. The south, midwest, and eastern US experienced large increases in thermal capacity, whereas in the west, where hydroelectric sources were more abundant, fossil-fuel capacity lagged. From the figure, it is also clear that the growth in thermal capacity was driven both by the construction of new larger power plants and expansions to existing plants.

Figure 3 shows that coal consumption for electricity generation grew rapidly and was a rising share of overall consumption. Coal consumption was 38.4 million short tons in 1938 and 211.3 million short tons in 1963. Coal consumption grew rapidly, but less rapidly than kilowatts generated (5.5 times vs. 8.1 times), because newer larger plants were more efficient than older smaller plants. 97 percent of the coal used was bituminous coal.[6] As a share of overall consumption, coal consumption for electricity generation rose from 10 percent to 50 percent, as other uses such as coal for home heating and coal for railways declined.

Coal-fired plants emitted large amounts of pollution. During this time period, the primary mitigation of pollution came from siting of the plants further from population centers, as advances in transmission technology allowed electricty to be shipped over longer distances. Figure 4 displays the density of thermal capacity around the 50 largest cities in the United States.[7] In both time period, the largest mass of plants are concentrated within 75 miles of

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[5] Natural gas and petroleum-fired generation was 20 percent in 1938 and 28 percent in 1963. Nuclear came online in 1957 and was less than 0.4 percent of generation in 1963.

[6] Anthracite coal by use is only reported beginning in 1954. In 1954 it was 3 percent and it remained small through 1963. United States Bureau of Mines, Minerals Yearbook (1958), Table 38 (anthracite), p. 188. Table 53 (bituminous), p. 102.

[7] Because area increases with the square of distance, the figure is constructed so that a uniform distribution would appear as a flat line in the figure.

the city-centroids. Nevertheless, the distribution flattens by 1960, as a larger share of power plants are located further away from city centers.

A second mitigating factor was smoke stack height. Figure 5 shows that the average stack height installed in a given year was roughly flat over the period 1938-1963 and was below 100 meters. Stack heights began to rise in the late 1960s. Experimentation with scrubbing began in the late 1960s in the United States and continued in the early 1970s (Biondo and Marten). Thus, pollution control came after the end of our sample period. There were efficiency gains in electricity generation – pounds per kilowatt-hour fell from 1.4 to 0.86, however these gains were swamped by the increases in coal consumption.

The precise emissions factors of particulates, sulfur dioxides, and nitrogen oxides depend on the properties of the coal and the design of the boiler.[8] Sulfur dioxides and nitrogen oxides are relevant, because they contribute to the formation of fine particulates. Unfortunately, there is little evidence on power plant emissions from 1938-1963, although, as we discuss shortly, we use data from air pollution monitors, mostly in urban areas, beginning in 1953 to link coal generation to increases in air pollution. A 2010 GAO report showed emissions by unit age. Plants built in the 1950s emitted far more sulfur dioxide per MW than units build in the 1960s.[9]

2.2 Human Exposure to Air Pollution

During the early and mid twentieth century, coal consumption was a major source of urban air pollution. Although systematic cross-city information on pollution levels was not available until the mid-1950s, intermittent monitor readings during the early 20th century (summarized in Table A.1) suggest the problem was severe. Measures of sootfall from New York and Pittsburgh report high levels into the mid-1940s.[10] The Ives et al (1936) study of 14 major cities in 1931 and 1932 performed time of day, day of week, and season of year

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[8] Environmental Protection Agency (1998).

[9] United States General Accountability Office (2012), Figure 5, p. 9.

[10] See Davidson and Davis (2005) for Pittsburgh and Eisenbud (1978) for New York.

analysis to separate the effects of coal from home heating and other pollution, much of it from coal used for industry and electricity.

It is worth noting that industrial and utility coal consumption were not the sole sources of human exposure to air pollution, since the correlation between indoor and outdoor pollution is high.[11] Humans were also exposed to particulates through sources such as transportation and from smoking. On-road vehicles were a small share of particulates – 1 percent of PM10 in 1940 and 2 percent in 1960.[12] Cigarettes and other burned tobacco products were a significant source of particulates for smokers and individuals exposed to second hand smoke. The available evidence suggests that consumption was trending up smoothly after the Great Depression.[13] Nevertheless, it is unlikely that these alternative sources of air pollution were systematically related to changes in coal consumption by power plants.

2.3 Pollution, Electricity, and Infant Mortality

Pollution is harmful to infant health. Chay and Greenstone (2003a, 2003b), Currie and Neidell (2005), and Currie and Walker (2011) examine the effects of permanent declines in pollution on infant mortality in the U.S. Currie, Neidell, and Schmeider (2009) use detailed data on pollution exposure of pregnant mothers to examine within-mother differences in birth outcomes. Knittel, Miller, and Sanders (2012) investigate the relationship between temporal changes in pollution caused by traffic shocks and infant mortality. Arceo-Gomez, Hanna, Oliva (2012) use a similar strategy to examine pollution and mortality in Mexico. Clay and Troesken (2010) link variation in weather-related London smogs to all-age mortality.[14]

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[11] A recent review article by Avery et al (2010) on the contemporary relationship between ambient PM2.5 and personal PM2.5, as measured by person-level monitors, finds that the two are positively correlated (0.54) and that personal air pollution is higher on average than ambient pollution due to higher indoor levels. Indoor air pollution levels tend to be more stable over time than outdoor levels, as increases and decreases in pollutants change with a lag. The lag depends on the air exchange rate, which tended to be high historically and is lower today (Nagada and Rector 1986). Thus, the correlation between indoor and outdoor levels was likely to have been higher historically.

[12] Environmental Protection Agency (2000).

[13] During the period 1920-1960, consumption was steadily rising, with the exception of a brief downturn during the Great Depression. Per capita consumption of tobacco that was consumed in burned form (cigarettes, cigars, pipes, roll your own) was roughly 6 pounds in 1920 and 12 pounds in 1960.

[14] See also Pope et al (1992), Clancy et al (2002), Hedley et al (2002), and Pope et al (2007).

For infants, particulates cause mortality population through two primary mechanisms. The first is prenatal. Curry and Walker (2011) use a natural experiment – the replacement of manual tolling with EZ Pass – which greatly reduced idling and local pollution. Higher levels of particulates were associated with greater likelihood of premature delivery and low birth weight. The second mechanism is postnatal effects on respiratory and cardiovascular outcomes. Using U.S. infant birth and death records covering 1999-2002, demographic characteristics, and pollution data Woodruff et al (2008) find increased particulates caused respiratory-related infant mortality. Using data from Mexico, recent work by Arceo-Gomez et al (2012) supports the link between pollution and infant mortality from respiratory and cardiovascular causes.

Access to electricity is linked to declines in infant mortality (Lewis 2014, Gohlke 2011). The mechanisms appear to be related to a decline in cost of keeping the house, dishes, clothes, and people clean and to additional free time that can be devoted to health promoting activities. Electricity enabled vacuum cleaners, dishwashers, and washing machines. In rural areas, it also powered electric pumps, which enabled households to have running water and indoor plumbing. Declines in these costs, often lead to increased consumption of cleaning services. For example, the diffusion of the modern washing machine led women to increase the frequency of clothes washing (Schwartz Cowan, 1983). Some accounts suggest that modern appliances offered a 4-person family roughly 20 hours per week in time-savings on home production (Greenwood and Seshadri, 2005). Families could reallocate time towards health promoting activities (Mokyr, 2000; Lewis, 2014).

Information on infant care and hygiene practices was disseminated through popular magazines, motion pictures, milk depots, and one-on-one visits from nurses (Ewbank and Preston, 1989; Moehling and Thomasson, 2012). Recent evidence from the developing world suggests that parental time is an important input to infant health (Miller and Urdinola, 2010). Given that pollution and electricity have opposite effects on infant mortality, any empirical effect found later will a net effect.

During the period of our study, women were unlikely to have many compensating behaviors, because, scientific evidence on the health costs of pollution was limited. Although public health officials and interested observers hypothesized that air pollution might be linked to mortality, but the evidence was unclear and some individuals argued that pollution might be health promoting. It was not until the 1990s that the epidemiological literature convincingly documented the link between airborne particulates and mortality (Laden et al 2006, Pope et al 2002).[15]

2.4 Pollution, Electricity, and Housing Prices

Because the understanding of the pollution-health relationship was weak, it is unclear whether individuals in our period are reacting to air pollution as a mortality risk or merely as a nuisance. Air pollution has historically been viewed as a negative externality. By the late nineteenth and early twentieth centuries, air quality in U.S. cities was bad enough that it had become a significant source of concern. The health effects were not well understood – and would not be well understood for decades – but the cleaning and other costs associated with high levels of pollution were clear. As smoke became significant, cities often passed legislation aimed at reducing it. In 1912, the Bureau of Mines reported that 23 of 28 cities with populations over 200,000 were trying to combat smoke.[16] The remaining five used relatively little coal and so were not significantly affected. Dozens of smaller cities also passed legislation (see Table A.2 for a summary of smoke abatement legislation prior to 1930). Historical evidence suggests that the wealthy tended to live in or move to locations with fewer negative externalities, often the neighborhoods were more distant from or higher than factories and power plants.

Empirical research on the effects of pollution on property values began to take off in

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[15] Most of the discussion focuses on particulates, since most of the early measurement of air pollution involved particulates, and most of the epidemiological work has been done on particulates. Particulates are highly correlated with other coal-related emissions such as carbon monoxide and sulfur dioxide. Some recent studies that use detailed monitor data are able to separately examine the effects of particulate, carbon monoxide, and sulfur dioxide on mortality.

[16] Goklany (1999), p. 15.

the 1960s. In 1967, Ridker and Henning published "The Determinants of Residential Property Values with Special Reference to Air Pollution," one of the first significant empirical analyses. Later work would build on this work. Cropper and Oates (1992) had an influential survey of subsequent work on housing and the difficulties of identifying effects. Chay and Greenstone (2005) and later work used instrumental variables to identify the effect of pollution on property values.

The literature on electrification and property values is sparser. In the United States in the mid-twentieth century, Lewis and Severini (2014) and Kitchens and Fishback (2013) find positive relationships between electrification and housing values, rents, and agricultural land values. In Brazil, Lipscomb et al (2013) find a 10 percent increase in electrification led to a 6 percent increase in property values.

3 Data

The empirical analysis links changes in local power plant emissions to air quality, mortality, and the housing market. Our data are drawn four main sources: Federal Power Commission Reports on thermal power plant coal consumption, air quality measures from the Environmental Protection Agency (EPA), county-level infant mortality rates from the Vital Statistics of the United States, and home values and other county-level covariates available in the Censuses of Housing and Population. With the exception of the Census information, all data have been digitized from original sources.

We first require a county-level measure of power plant emissions. To construct this measure, we digitize annual plant-level data on electricity production and fuel consumption for the period 1938-1962 from Federal Power Commission Reports.[17] These data provide annual information on the amount of coal burned for energy production for approximately 500 of the largest thermal power plants in the US, representing 90% of all power plant

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[17] Federal Power Commissions Steam-Electric Plant Construction Cost And Annual Production Expenses series (U.S. Federal Power Commission, 1947-62).

coal consumption nationwide. We combine these data with georeferenced information on power plant location, based on a set of seven maps of the power industry (Federal Power Commission, 1962).

Our preferred measure of local pollution is constructed as total power plant coal consumption within 50 miles of the county-centroid. This distance was chosen to capture the fact that the majority of power plant emissions are dispersed locally (see Seinfeld and Pandis (2006) for a review of the mechanics of airborne pollutant transport).[18] We construct a second measure of annual power plant coal consumption (within 50 miles of the county-centroid) driven solely by the construction of new power plants. Given the longevity of thermal power plants, which range from 30 to 50 years, site locations were primarily made on the basis of long-term projected demand. As a result, variation in this second measure should be exogenous to contemporaneous demand for electricity.

We obtain county-level information on air quality based on monitor data obtained from the EPA, which cover all monitors from 1957 to 1962.[19] The monitoring stations are located at ground level, and report measures of TSP concentration ($\mu g/m^3$). For each monitor, we construct annual TSP concentration as the average of these readings. Because particulate matter has a relatively short atmospheric life – ranging from 10 days to several months – these annual measures should reflect the effects of contemporaneous emissions.[20] Monitors were typically placed in locations with higher levels of pollution. For counties with at least one monitoring station, annual county-level TSP concentration is constructed as the average TSP levels across all monitors within the county boundaries. Figure 6 presents the sample of 75 counties with information on air quality.

To study the effects of local emissions on health, we use annual county-level data on infant

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[18] Recent evidence from Illinois found that over two-thirds of PM2.5 exposure occurs within 125 miles of a power plant (Levy et al., 2002). Given substantial increases in average smoke stack heights over the past 50 years (see Figure 5), air pollution was likely far more localized during the 1940s and 1950s.

[19] We are also in the process of digitizing additional air quality measures from the *Air Pollution Measurements of the National Air Sampling Network: Analysis of Suspended Particulate Samples Collected, 1953-1957*, which will allow us to extend the analysis to the period 1953 to 1962.

[20] Atmospheric lifespan is also an important determinant pollution transport. Relative to longer-lived pollutants, such as carbon dioxide, TSP emissions are far more locally concentrated.

mortality drawn from the *Vital Statistics of the United States*. Price Fishback digitized the data from 1938-1951, and he kindly shared the data with us. We digitized additional data for the period 1952-1954. By focusing on infant mortality, we hope to reduce misspecification caused by the fact that health capital is a function of both current and previous pollution levels. For these regressions, we construct an unbalanced sample of 1,208 counties for the period 1938 to 1954. The main sample is constructed as counties reporting infant mortality rates in at least three-quarters of the sample years, along with information on housing prices and economic characteristics for the census years 1940, 1950, and 1960. Additionally, power plant coal consumption must be positive in at least one of the sample years. Figure 7 presents the sample selection for the mortality analysis. Given the distribution of coal capacity, our sample is primarily concentrated in the eastern half of the US.

We rely on county-level property values from the Census of Housing for 1940 to 1960 (Haines and ICPSR, 2010; DOC and ICPSR, 2012) to study the effects of power plant emission on the housing market. Our main outcomes of interest are (decadal) median dwelling value and (decadal) median dwelling rent. The 1940 Census of Housing also reports information on the proportion of households with electric lighting, which is used as a proxy for baseline electricity access. We also rely on state-level bituminous coal consumption per square mile in 1927 (Tryon and Rogers, 1927), the closest year for which detailed statistics are available, to proxy baseline exposure to pollution. We divide counties into nine bins based on the measures of baseline electricity access and pollution exposure. As we discuss further in the identification section, this categorization will be used to explore heterogeneity in the housing market response to local thermal emissions.

Additional data is used as controls in our analysis. "Geography" variables include time-varying controls for annual precipitation, temperature, degree days below 10C, and degree days above 29C, and county latitude and longitude. [Source] "Economy" covariates include total employment, manufacturing employment, and manufacturing payroll per worker at the baseline from the Census of Manufactures (1940).

Table 1 presents the levels of TSP concentration in the late 1950s and early 1960s. The average TSP concentrations among the sample of 75 counties was above 100 $\mu g/m^3$ in almost every year in our sample. This is double the current National Ambient Air Quality Standards (NAAQS) for particulate matters. Levels of pollution were not homogeneous across the nation, and monitors were typically placed in locations with higher levels of pollution. For example, the 14 cities reporting air quality measurements in the 1930s had higher levels of pollution in the 1950s. Pollution levels were trending over this time period. Between 1957 and 1962, average TSP concentration in the sample fell from 141.5 to 100.5 $\mu g/m^3$. Many factors may have contributed to that decline. Among them, we would point out the expansion of the power grid, which allowed electric utilities to install power plants further from the city center, and the replacement of coal with natural gas for home heating, which reduced coal consumption in the urban core.

Despite the downward trend in air pollution, coal consumption by electric utilities is increasing in those years. Among our core sample of counties in the empirical analysis, coal consumption within 50 miles of the county-centroid rose from 200,000 tons to over 1 million tons over this period (see Figure 8). There is a steady upward trend until to the onset of the V-shaped recession of 1953, when coal consumption reduces considerably. Nevertheless, as the economy recovers, coal use in power generation jumps to levels never seen before, more than doubling by mid-1950s. There was considerable heterogeneity in these changes in coal consumption across counties. Smaller counties increased coal utilization for power generation proportionally more than larger counties, even though the levels of consumption for those larger counties were somewhat higher in the baseline.

Figure 9 presents trends in the infant mortality rate (per 1,000 live births) for the sample of counties. Between 1938 and 1954, infant mortality fell by almost 50%. In part, these health improvements reflect advances in medicine, such as the introduction of sulfa drugs in the late 1930s, and the available of penicillin after World War II. Declines in household coal-use may also have played a role in these health improvements (Barreca, Clay, and Tarr, 2014). This study will investigate whether rises in coal-fired power generation counteracted these health improvements, dampening the overall declines in mortality during this period.

4 Empirical Strategy

4.1 Annual variation in coal consumption by electric utilities

Our first empirical strategy exploits spatial and temporal variation in annual coal consumption by electric utilities to study the effects of local plant emissions on air quality, health, and the housing market. In the baseline empirical specification, we regress outcome Y in county c in year t on local power plant emissions, $Emissions_{ct}$, year fixed effects, δ_t, county fixed effects, η_c, and a linear state trend, λ_{st}.[21] In addition, we include a vector of time-varying covariates for geography (annual precipitation, temperature, degree days below 10C, and degree days above 29C, and latitude and longitude), X_{ct}, invariant controls for county longitude and latitude, Z_c, interacted with the year fixed effects, δ_t, and baseline county economic characteristics, $Econ_c$ (total employment, manufacturing employment, and manufacturing payroll per worker in 1940), interacted with δ_t. The estimating equation is given by

$$Y_{ct} = \alpha + \beta Emissions_{ct} + \theta X_{ct} + \delta_t Z_c + \delta_t Econ_c + \lambda_{st} + \eta_c + \delta_t + \epsilon_{ct}. \qquad (1)$$

The variable of interest, $Emissions_{ct}$, is measured as total power plant coal consumption (in 100,000s of tons) within 50 miles of the county-centroid. We estimate equation (1) separately using all variation in annual thermal coal consumption. The estimate of interest, β, captures the reduced form impact of thermal emissions on air quality, health, and housing prices. Standard errors are clustered at the county-level to adjust for heteroskedasticity and within-county correlation over time.

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[21] In some specification, we replace λ_{st} with a vector of state-by-year fixed effects.

The identifying assumption requires that annual changes in plant emissions are unrelated to contemporaneous determinants of infant health and housing prices. This assumption will be satisfied if annual variation in coal consumption was driven primarily due to long-term planning, for example, as a result of changes in power plant capacity. In contrast, if variation in coal consumption was driven by short-term fluctuations in demand, the term $Emmissions_{ct}$ might be correlated with the error term, leading to inconsistent estimates in equation (1). For example, improvement in local economic conditions may have simultaneously increased local plant emissions and improved infant health, which would lead the estimates of β to be downward biased. To mitigate these concerns, we consider alternative specifications which control directly for measures of baseline economic conditions interacted with year fixed effects.

4.2 Difference-in-differences based on openings of power plants

Because annual variation in power plant coal consumption may be correlated with unobservable determinants of infant health, we consider an alternative estimation strategy based on openings of new power plants. We adopt a difference-in-differences strategy comparing the relative change in infant mortality in counties within 25 miles of a power plant to those between 25 and 125 miles before and after opening.[22] By comparing across these two groups, we are able to identify the impact of mortality driven by pollution, controlling for time-varying local determinants of health. Importantly, previous work suggests that the impact of a power plant opening on local electricity access are constant within 60 miles of a plant and then decline with distance (see Lewis and Severnini, 2015). As a result, both treatment and control counties should benefit similarly from the impact of a newly operational plant.

We investigate the effect of power plant openings on infant mortality by estimating the

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[22] We explore the sensitivity of the results to various radii around a plant. Our primary specification is consistent with pollution transport models (Seinfeld and Pandis, 2006).

following econometric model:

$$\begin{aligned} IMR_{pdt} = &\beta_0 + \beta_1 1[PPopen]_{pt} + \beta_2 1[d < 25mile]_{pd} + \beta_3 1[PPopen]_{pt} \times 1[d < 25mile]_{pd} \\ &+ \eta_{pd} + \tau_{st} + \beta_4 X_{pd} \times \xi_t + \epsilon_{pdt} \end{aligned}$$

where IMR_{pdt} denotes infant mortality rate near plant site p, within distance group d, in year t. For each plant, there are two observations per year: treatment counties (within 25 miles of the plant) and control counties (between 25-50, 25-100, and 25-125 miles of the plant).

The variable $1[PPopen]_{pt}$ is an indicator for whether plant p is operating in year t, and $1[d < 25mile]_{pd}$ is equal to one for counties within 25 miles of a current or future plant site. We include a vector of plant-by-year fixed effects, η_{pd} to control for time-invariant determinants of infant mortality at the plant-by-year group. The equation also includes state-by-year fixed effects, τ_{st}, to flexibly allow for state trends in infant mortality. Additional geographic covariates and baseline attributes, X_{pd}, are interacted with year fixed effects. The parameter of interest is β_3, which captures the differential impact of an open plant on mortality in counties near a power plant relative to those slightly further away. This coefficient captures the impact of localized pollution on infant health. To the extent that pollution transport exceeded 25 miles, this estimate captures a lower bound of the impact on health.

4.3 Heterogeneous responses to new thermal power plants

Finally, we examine how the pollution costs were traded-off against the various benefits of thermal power. In particular, we investigate heterogeneity in the housing market response according to initial county characteristics. Counties are grouped into one of nine bins (high, medium, and low), according to both initial pollution and initial access to electricity. For example, $(H - PHHL1940 \times H - CCSM1927)$ denotes a county in the top tercile of initial electricity access pollution. We interact these baseline characteristics with two measure of local coal consumption: total coal consumption within 50 miles of county centroid and county distance to the nearest large (>50mw) power plant according to the following regression model:

$$\begin{aligned} Y_{ct} =& \alpha + \sum_{i \in \{L,M,H\}} \sum_{j \in \{L,M,H\}} \gamma_{ij} \big(Emissions_{ct} * i - PHHL1940_c * j - CCSM1927_c \big) \\ &+ \theta X_{ct} + \delta_t Z_c + \delta_t Econ_c + \lambda_{st} + \eta_c + \delta_t + \epsilon_{ct}. \end{aligned}$$

Where Y_{ct} denotes either median dwelling value or median dwelling rent in county c, in year t. Equation (2) includes the same set of covariates as the baseline model. The variables of interest are now interaction the baseline characteristics with the $Emissions_{ct}$. The nine estimates of γ_{ij} capture the housing market response to changes in local coal consumption in each of type of county according to baseline baseline electricity access and baseline pollution.

The response across these 9 bins will depend on how the pollution costs and local benefits of electricity production vary according to these baseline characteristics. Intuitively, at low rates of electrification, it might be expected that the benefits from expanding access will exceed the costs associated with air pollution as there is greater scope for increased energy production to expand residential access. Alternatively, heterogeneity in the housing market response according to baseline pollution will depend both on the functional form of the dose-response curve – how a marginal change in emissions affects health at various levels of pollution exposure –, and cross-county residential sorting based on preferences for clean air.

5 Results

5.1 Estimated Effects on Local Air Quality

Table 2 reports the estimated effects of local thermal coal consumption on county-level TSP concentrations. Columns (2) to (5) report the estimates of $Emissions_{ct}$ from the estimating equation (1) across a range of specifications. Column (2) includes only state and year fixed effects, column (3) adds a linear state trend, column (4) includes the county-level controls for geography and economic conditions, and column (5) adds count fixed effects. With the exception of column (5), these regressions rely on cross-sectional rather within-county variation to identify the effects of coal consumption on air quality. The fixed effects estimation strategy has the advantage of controlling for underlying county-level characteristics that might simultaneously influence coal-use and pollution levels. The drawback of this technique is that a large fraction of the variation in TSP levels is thrown out. Given the short time horizon and the limited number of counties with air quality measures, the fixed effects regressions generally lack precision. The regressions are estimated for an unbalanced panel of 75 counties for the period 1957 to 1962. We estimate equation (1) using two different annual measures of coal consumption: all variation in power plant consumption for plants with 50 miles, and variation driven solely by the construction of new power plants.

In all specifications, local electric utilities coal consumption is negatively related to county air quality. The first row reports the estimates based on all annual variation in thermal power plant coal consumption. The inclusion of economic covariates (column 3) reduces the magnitude of the estimates by 40%. Nevertheless, the point estimates remain large and statistically significant, even after controlling for measures of local economic activity. Controlling for county fixed effects (column 4) reduces both the magnitude and precision of the point estimates. The second row reports the results driven by newly constructed power plants. We find a similar relationship between coal consumption and TSP concentration. The fact that the two different measures thermal emissions deliver quantitatively similar results provides confidence in the estimation strategy, given that decisions over annual power plant coal consumption were much more responsive to contemporaneous economic conditions than decisions regarding the timing of power plant openings.

Together these results imply that thermal power plants were a significant contributor to local air pollution. Over the period 1957 to 1962, TSP concentration fell by 41.1 ($\mu g/m^3$) across the sample of cities. Our estimates imply that the declines in TSP levels would have been between 7% and 12.6% larger had thermal coal consumption remained at its 1957 level.

We can apply these estimates to assess the importance of thermal power generation for longer-run trends in pollution. For a sample of 14 cities, we have TSP readings in both 1931-33 and 1962, along with information on thermal coal consumption. Over this time period, TSP levels fell from 510 to 129.6 $\mu g/m^3$. At the same time, electric utility coal consumption per year rose by 1.6 million tons . Applying the estimates in Table 2, we calculate that TSP concentrations would have decline by an additional 10.7 $\mu g/m^3$, had thermal capacity remained at its baseline level.[23]

5.2 Estimated Effects on Infant Mortality

Given the negative relationship between coal-use for electricity generation and local air quality, one might expect these plants to have had negative effects on the health of the local population. We examine this question by regressing annual county infant mortality rates on local thermal coal consumption over the period 1938 to 1954. Table 3 reports these results. Columns (1) to (5) report the estimates of $Emissions_{ct}$ for different specifications. In column (1) we include only year and county fixed effects; in column (2) we add a linear state trend; in column (3) we include time-varying covariates for economic and geographic characteristics; in column (4) we add controls for initial household electricity access and local hydroelectric

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[23] These out-of-sample calculations require that the relationship between power plant coal consumption and local TSP concentration was stable over this time period. In practice, there were significant improvements in boiler technologies and increases in smoke stack height during this period. These changes would likely weaken the relationship between plant emissions and pollution, so our estimates should be considered a lower bound.

capacity; and in column (5) we replace the linear state trend with a state-by-year fixed effect.

Table 3 reports the results based on all annual variation in coal consumption. The point estimates range from 0.168 to 0.053 and are all statistically significant. Notably, the inclusion of economic covariates reduces the point estimate from 0.091 to 0.067 (column 2 to 3). The change in the estimate could reflect the fact that growth in thermal capacity and industrial activity were positively related. Failing to account for the direct impact of industrial pollution on health would lead the estimates in the first two columns to be upward-biased.

Between 1938 and 1954, the infant mortality rate fell from 53.3 to 28.2. Our estimates imply that infant mortality rates would have fallen by an additional 3 percent, had power plant coal consumption remained at its 1938 level. We apply these estimates to calculate the total number of infant deaths between 1938 and 1954 that were caused by increased thermal coal consumption. We calculate the average annual change in coal consumption relative to 1938 for the counties in our sample. We then multiply this change by the point estimate (divided by 1,000) and the total number of live births in the sample to calculate excess mortality in each year between 1939 and 1954.[24] Our preferred estimates (column 5) imply that 12,720 infant deaths would have been averted had power plant coal emissions remained at their 1938 level.

In Table 4, we report the estimates from the difference-in-differences estimation strategy based on new plant openings. Across all five specifications, the point estimates are positive and statistically significant. The findings are significant across the four alternative control groups. The fact that the point estimates are smaller in absolute magnitude using the control group between 25 and 50 miles of a plant is consistent a decline in health in the comparison group due to pollution transport. As a result, these results should be viewed as a lower bound for the infant mortality effect. The point estimates imply that the construction of a new large power plant is associated with a 2% increase in infant mortality. Given that plants

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[24] For example, in 1946 excess mortality is calculated as follows: $\big(\bar{Coal}_{1946} - \bar{Coal}_{1938} \times \beta/1,000 \times Livebirths_{1946}\big) = (12.76 - 6.15) \times 0.083/1,000 \times 1,628,579 = 894$ infant deaths.

were historically concentrated in densely populated areas, these findings imply substantial health costs associated with power generation.

In fact, the results in Tables 2 and 3 can be combined to assess the relationship between local TSP concentration and infant mortality. Intuitively, power plant emissions can be thought of as an instrument for local air quality. We can construct a Wald Estimator for the effect of TSP concentration on health by dividing the 'reduced form' impact of thermal generation on health by the 'first stage' relationship between thermal generation and air quality.[25] We calculate that a 1% increase in TSP concentration is associated with a 0.15 to 0.29 percent increase in infant mortality. These findings are roughly in line with more recent evidence on the health hazards of particulate matter. For example, Chay and Greenstone (2003) calculate that a 1% in local TSP concentrations is associated a 0.35% increase in mortality during the 1980s.

5.3 Nonlinearities in the Health-Response

The fact that the relationship between TSP concentration and mortality appears to have strengthened over 20th century is surprising. Advances in medical care and greater public awareness of the hazards of pollution should tend to dampen this relationship. One possibility is that these trends reflect a nonlinear dose-response relationship. Specifically, that the marginal impact of a reduction in TSP levels is greater at lower initial pollution levels.[26]

To investigate the possibility of a nonlinear dose-response, we estimate a generalized version of equation (1), in which the marginal impact of change in power plant emissions is allowed to vary across six different levels of contemporaneous coal consumption. Intuitively, these regressions allow the health effects of pollution to vary according to baseline exposure.

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[25] Underlying this approach is an exclusion restriction, which requires that thermal plant emissions affected health solely through their impact on TSP concentration. To the extent that local coal consumption affected air quality more generally – for example, through increased sulfur dioxide or nitrogen oxide levels – these estimates will overstate the relationship between TSP and mortality.

[26] Chay and Greenstone (2003) find that changes in TSP pollution had larger effects on infant mortality in lower initial pollution levels.

The results are reported in Table 5. The estimated effects of coal consumption are systematically larger in counties with lower baseline coal consumption. The estimate of β is almost twice as large in counties with less than 500,000 tons of baseline coal consumption relative to counties with more than 8 million tons of coal consumption, implying that a one standard deviation increase in power plant emissions would cause an additional 1.5 infant deaths per 1,000 live births in these low coal counties.

The analysis reveals a nonlinear relationship between power plant emissions and infant mortality. These findings are consistent with previous studies that estimate a nonlinear dose-response curve. In particular, previous studies typically calculate larger marginal impact of pollution exposure at low levels of baseline exposure (see Pope et al., 2011; Pope et al., 2004).

There are several reasons why this relationship may vary according to initial pollution exposure. First, the impact of a marginal increase in coal consumption on local air quality could vary with baseline levels of pollution. The process through which the primary pollutants associated with thermal generation (nitrogen oxides and sulfur dioxides) are converted into atmospheric suspended particulates is complicated and highly nonlinear.[27] Moreover, if baseline levels of pollution were partially influenced by the preferences of the local population – for example, via lobbying of local officials – we would expect to observe higher initial levels of pollution in regions with strong average wind patterns, where the costs of local emissions would fall on downwind jurisdictions. In this scenario, the impact of a marginal increase in power plant emissions on the health should be systematically lower in counties with high levels of initial pollution. In principle, this explanation could be examined by investigating how the relationship between changes in coal consumption and TSP concentration varying according to baseline pollution levels. Unfortunately, given the limited number of counties with monitor information, and the fact that monitors were placed almost exclusively in locations with high initial levels of pollution, the data contains too little variation to examine

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[27] The relationship depends on a variety factors including temperature, precipitation, humidity and wind speed.

this question.

A second possibility is that the heterogenous effects reflect differences in the pathophysical response to changes in air quality according to initial pollution exposure. Maternal exposure to TSPs pollution over her lifetime and during pregnancy could interact new local emissions to either mitigate or reinforce the consequences of infant exposure.

Third, residential sorting could lead to differences in average population characteristics across counties, which could lead to different responses across counties. For example, if less-healthy individuals selected into low pollution counties, they might be more susceptible to the consequences of a marginal increase in emissions. Similarly, if within-county residential sorting were related to baseline pollution levels, we might observe differences in the response across counties as a result of residential segregation.

Although we cannot distinguish between these competing explanations, it is noteworthy that we estimate substantial heterogeneity during a period in which populations were uninformed of the health hazards associated with outdoor air pollution. As a result, residential sorting on the basis of health preferences should be far less pronounced in this time period. In future analyses, we will investigate the importance of public information, comparing how the mortality gradient evolved before and after the passage of 1963 Clean Air Act.

5.4 Effects in the Housing Market and Labor Market

Together, the results from Tables 3 to 5 show that local power plant emissions were harmful for health. These findings are consistent with recent evidence on the effects of local coal consumption on mortality (Currie et al., 2013; Hanlon, 2014). Nevertheless, it is unclear how individuals traded-off these health costs against the benefits of local thermal electricity. To investigate this question, we adopt a hedonic approach, using changes in the housing market and wages to infer the implicit price associated with this nonmarket amenity. We estimate the relationship between coal consumption by electric utilities and housing prices for decennial years 1940, 1950, and 1960.

Table 6 presents the estimates of the capitalization of power plant coal-use into property values and wages. We report the estimates using county-centroid distance to the nearest large steam power plant, although the qualitative results are similar based on annual coal consumption (see Table A.4). The point estimates capture the reduced form impact of a 10 mile decrease in distance to a plant. Panel A reports the estimates for the logarithm of median rent. Once the regressions are adjusted for state trends and economic covariates all the estimates become small and statistically insignificant. Across a variety of alternative specifications, the point estimates range from -0.0004 to 0.0002. The substantial increase in thermal coal-use between 1940 and 1960 can explain less than 1% percent of variation in housing prices over this period.

In Panel B, we assess the impact thermal power on local wages. These models help assess whether firms compensated workers for local pollution through higher wages. This situation could arise if low cost electricity offered productivity benefits to industry. Across all five regressions we estimate small and statistically insignificant effects for wages.

There are several possible explanations for the limited response in the housing or labor market. First, the findings might simply reflect the fact that individuals were unaware of the health costs associated with pollution, and thus generally unresponsive to changes in local coal consumption. Media coverage during this time period did identify the potential risks associated with pollution, however, epidemiological evidence on the link between pollution and mortality did not emerge until the 1970s. Alternatively, if there was heterogeneity in tastes for clean air, individuals may have sorted across locations on the basis of the unobservable preferences. In this case, our estimates of the marginal willingness to pay (MWTP) could reflect the preferences of a specific subpopulation that, for example, may have placed a relatively low value on clean air. Third, the findings may simple capture the fact that individuals valuations of the benefits associated with local electricity generation roughly offset the pollution costs. To differentiate amongst these competing explanations, we exploit heterogeneity in the housing market response.

5.5 Heterogeneous Responses in the Housing Market

To assess heterogeneity in the effects of thermal emissions, we split US counties into nine bins according to baseline air pollution and electricity access. Air pollution is proxied by coal consumption per square mile in 1927 (CCSM1927), and electricity access is proxied by the proportion of homes with electric lighting in 1940 (PHHL1940). The bins represent each tercile – low, medium, and high – of the distribution, so that ($L - PHHL1940 \times M - CCSM1927$) denotes a county in the bottom tercile of electricity access and the medium tercile of pollution exposure. We then interact these each bin with our main measure of thermal coal consumption, $Emissions_{ct}$.

Table 7 presents the results for the logarithm of dwelling rent. The small effects found in Table 6 mask substantial heterogeneity in the housing market response, and the point estimates differ widely across the 9 bins. To interpret this heterogeneity, we first compare impact of coal consumption across the three different levels of electricity access: L-PHHL1940, M-PHHL1940, and H-PHHL1940. The estimates are systematically more negative in counties with higher baseline levels electricity access. For example, in low pollution counties (L-CCSM1927) the point estimates range from 0.006 in low access counties to -0.010 in high access counties.

This heterogeneity captures how the tradeoffs of power plant coal consumption evolve as a greater share of the population electrify. At low levels of electricity access, increases in energy production offer large potential benefits to the local population. As a greater fraction of the population gain access, the scope for these gains is diminished. On the other hand, the pollution costs of power generation are generally independent of electricity access. Individuals will assign more value the amenity benefits associated with increases in electricity production at low levels of electricity access, and place greater importance on the pollution costs of coal consumption at high levels of access. As a result, the MWTP to avoid power plant emissions should increase with the level of electricity access, consistent with the heterogeneity we observe in the hedonic regressions.

The fact that the MWTP to avoid power plant emissions depends on the level of electricity access has important implications for energy policy. Fossil-fuel generators have long lifespans, ranging from 30 to 50 years (IEA, 2010). Consider the case of the Gorgas power plant. This large thermal power plant was built in the late 1920s near the town of Parrish in Walker County, Alabama. Initially, 70mw of capacity were installed, and the plant consumed roughly 150,000 tons of coal per year. At the time of installation only 13% of residents had electrical services. Given these low levels of electricity access, our estimates imply that at the time of construction of this plant would have caused a 0.3% increase in local home values, generating a net gain of $379,000 (1990 USD) in the local housing market. By 1950, 90% of homes in Walker County had electrical services. As a result, the pollution costs would have overwhelmed the local benefits of greater electricity access, and led to a 0.9% fall in local home prices a total decline of $1,653,000 in the value of the county's housing stock. Given these large changes in the response of the housing market, policymakers must take careful account for the evolving preferences for thermal power when investing in energy infrastructure.

Next, we study whether baseline differences in pollution affected the housing market response to coal consumption. Table 7 also reports the impact of power plant emission across low, medium, and high baseline pollution exposure based on coal consumption per square mile in 1927.[28] We find systematic differences in the willingness to pay to avoid marginal increase power plant emissions across the three groups. The estimated effects of a change in power plant emissions are significantly more negative in counties with lower baseline pollution levels. In the top panel, for example, the estimates range from 0.026 in high coal counties to 0.006 in low coal counties. This general pattern is also robust to our alternative definition of local steam capacity (see Table A.5). On the other hand, we find no evidence that steam capacity had heterogeneous effects on local wages (see Table 8).

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[28] For example, the first three rows report the effects of thermal emissions across the three levels of exposure (L-CCSM1927, M-CCSM1927, and H-CCSM1927) for the sample of counties with low electricity access (L-PHHL1940).

There are two plausible explanations for the heterogeneous responses to coal emissions observed at the county level. First, the results could reflect nonlinearities in the relationship between local coal consumption and mortality. The dose-response relationship established in Table 4 reveals that a marginal increase in coal consumption had a larger impact on health in counties with low initial pollution exposure. Assuming this health gradient was capitalized in the housing market, the MWTP for an increase in electric utility emissions should be lower in low coal counties.

A second possibility is that these findings reflect residential sorting based on tastes for air quality. In this case, the observed housing price changes reflect the implicit valuation of a marginal change health across groups with different preferences. Even if the marginal impact of coal consumption were independent of initial pollution exposure, the response in the housing market need not have been constant across these distinct populations. Although we cannot rule out this explanation, the fact that the patterns found in Table 6 are stable across specifications including models that control for baseline economic conditions suggests that selection is unlikely to be driving the heterogeneity.

Changes in power plant coal consumption had substantial effects in the housing market. Depending on a county's initial conditions, the construction of a fossil fuel plant could be viewed either as a local amenity or disamenity. The average effects found in the baseline hedonic analysis mask this heterogeneity, as MTWP for greater electricity production in some counties was offset be the MWTP to avoid pollution in others.

The results show that air pollution (or something correlated with air pollution) was considered to be a disamenity by local residents. These results are striking, given that measures of local air were not available until the late 1950s, and environmental air pollution received limited attention from federal policymakers prior to the passage of the 1963 Clean Air Act. Perhaps the frequent media coverage on the potential hazards of pollution influenced public opinion. Alternatively, the results might simply reflect the fact that the soot and ash emitted by fossil fuel combustion were viewed as disamenities independently of their health effects.

These findings have relevance for current developing nations in which accurate air quality measures are not publicly available. In particular, they suggest that the costs associated with poor air quality might still be valued by residents even when official information is not made public.

6 Conclusion

This paper uses the sharp expansion in U.S. fossil fuel powered electricity during the mid-20th century to study the tradeoffs associated with thermal power generation. The analysis draws on newly digitized information on the timing of power plant openings, coal consumption, air quality and health. The results show that increases in power plant emissions are associated with higher levels of local pollution and a greater incidence of infant mortality. Although these negative environmental effects were not considered a disamentity on average, we find substantial heterogeneity in how individuals valued local thermal capacity. In particular, our estimates imply a positive MWTP for thermal power at low levels of electricity access, and a negative MWTP at high levels of access, suggesting that the benefits of electricity may diminish with economic development.

Our estimates suggest that there was a remarkable reversal in preferences for local thermal electricty during the mid-20th century. In 1925, the construction of a thermal power plant would have been considered a gain to local residents in the majority of U.S. counties, and a local disamenity in just 2% of counties. By 1955, fossil fuel power plants were viewed as a local disamenity in 98% of counties. Perhaps in response to these evolving preferences, the subsequent fifty years have witnessed increasingly stringent regulations of power plant emissions under the 1963 Clean Air Act and subsequent amendments. There were substantial costs associated with meeting these requirements, including costs associated with decommissioning existing plants and upgrading capacity to meet emission standards. Given these potentially large adjustment costs, policymakers must take into account both current and future preferences for electricity and air quality when making electricity infrastructure investment decisions.

References

Almond, Douglas, Yuyu Chen, Michael Greenstone, and Hongbin Li. 2009. “Winter Heating or Clean Air? Unintended Impacts of China’s Huai River Policy?”, *American Economic Review*, 99(2): 184-90.

Arceo-Gomez, Eva, Rema Hanna, and Paulina Oliva. 2012.“Does the Effect of Pollution on Infant Mortality Differ Between Developing and Developed Countries? Evidence from Mexico City.” NBER Working Paper #18349.

Avery, Christy L., et al. “Estimating error in using ambient PM2. 5 concentrations as proxies for personal exposures: a review.” *Epidemiology* 21.2 (2010): 215-223.

Barreca, Alan, Karen Clay, and Joel Tarr. (2013). “Coal, Smoke, and Death: Bituminous Coal and American Home Heating,” NBER Working Paper #19881.

Biondo, S. J., and J. C. Marten. “A History of Flue Gas Desulphurization Systems Since 1850.” *Journal of the Air Pollution Control Association* 27.10 (1977): 948-961.

Chay, Kenneth Y. and Michael Greenstone. 2003a. “The Impact of Air Pollution on Infant Mortality: Evidence from Geographic Variation in Pollution Shocks Induced by a Recession.” *Quarterly Journal of Economics*, 118: 1121-1167.

Chay, Kenneth Y. and Michael Greenstone. 2003a. “Air Quality, Infant Mortality, and the Clean Air Act of 1970.” MIT Department of Economics Working Paper No. 04-08.

Chay, Kenneth Y., and Michael Greenstone. “Does Air Quality Matter? Evidence from the Housing Market.” *Journal of Political Economy*, 113.2 (2005).

Clancy L, Goodman P, Sinclair H, Dockery DW. 2002. “Effect of air-pollution control on death rates in Dublin, Ireland: an intervention study.” *Lancet* 360:12101214.

Clay, Karen and Werner Troesken. 2010. “Smoke and the Rise and Fall of the London Fog” in *Climate Change Past and Present.* Edited by Gary Libecap and Richard H. Steckel. Chicago: University of Chicago Press, 2010.

Cohen, Aaron et al. 2004. “Chapter 17: Urban Air Pollution” in *Comparative Quantification of Health Risks, Volume 2.* Geneva: World Health Organization.

Cropper, Maureen L., and Wallace E. Oates. “Environmental economics: a survey.” *Journal of Economic Literature* (1992): 675-740.

Currie, Janet and Matthew Neidell. 2005. “Air Pollution and Infant Health: What Can We Learn From California’s Recent Experience?” *Quarterly Journal of Economics*, 120: 1003-1030.

Currie, Janet, Matthew Neidess, Johannes Schmieder. 2009. “Air Pollution and Infant Health: Lessons from New Jersey.” *Journal of Health Economics.* 28: 688-703.

Currie, Jarnet and Reed Walker 2011. "Traffic Congestion and Infant Health: Evidence from E-ZPass." *American Economic Journal: Applied Economics*, 3:65-90.

Davidson, C.I., and D.L. Davis. 2005. "A Chronology of Airborne Particulate Matter in Pittsburgh," in *History and Reviews of Aerosol Science*, G.J. Sem, D. Boulard, P. Brimblecombe, D.S. Ensor, J.W. Gentry, J.C.M Marijnissen And O. Preining (Eds.).

DOC (United States Department of Commerce) - Bureau of the Census. (2012). County and City Data Book [United States] Consolidated File: County Data, 1947-1977. ICPSR07736-v2. Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor].

Eisenbud, Merril. 1978. Levels of Exposure to Sulfur Oxides and Particulates in New York City and their Sources. *Bulletin of the New York Academy of Medicine 1978*, 54:991-1011.

Environmental Protection Agency EPA, AP42. *Compilation of Air Pollutant Emission Factors, Volume I Stationary Point and Area Sources.* (1998). http://www.epa.gov/ttnchie1/ap42/ch01/final/c01s01.pdf.

Environmental Protection Agency. 2000. *National Air Pollutant Emission Trends 19001998.* US Environmental Protection Agency (2000).

Fishback, Price, Michael Haines, Shawn Kantor, and Joseph Cullen. (s.d.). County and City Mortality Data, 1921 to 1950, available at *econ.arizona.edu/faculty/fishback.asp*

Gartner, Scott Sigmund, et al. *Historical statistics of the United States.* Ed. Susan B. Carter. New York: Cambridge University Press, 2006.

Gohlke, Julia M., et al. "Estimating the global public health implications of electricity and coal consumption." *Environmental health perspectives* 119.6 (2011): 821

Goklany, Indur M. *Clearing the air: the real story of the war on air pollution.* Cato Institute, 1999.

Haines, Michael R., and Inter-university Consortium for Political and Social Research (ICPSR). (2010). Historical, Demographic, Economic, and Social Data: The United States, 1790-2002. Ann Arbor, MI: Inter-university Consortium for Political and Social Research, icpsr.org.

Hales, Jeremy M. *Tall stacks and the atmospheric environment.* Environmental Protection Agency, Office of Air and Waste Management, Office of Air Quality Planning and Standards, 1976.

Hanlon, W. Walker. (2014). Endogenous City Disamenities: Lessons from Industrial Pollution in 19th Century Britain, Working Paper - University of California, Los Angeles.

Hedley AJ, Wong CM, Thach TQ, Ma S, Lam TH, Anderson HR. 2002. Cardiorespiratory and all-cause mortality after restrictions on sulphur content of fuel in Hong Kong: an intervention study. *Lancet* 360:16461652.

Ives, James et al. 1936. *Atmospheric Pollution of American Cities for the Years 1931 to 1933 with Special Reference to the Solid Constituents of the Pollution.* U.S. Treasury Department, Public Health Bulletin No 224. Washington: Government Printing Office.

Kitchens, Carl, and Price Fishback. *Flip the Switch: The Spatial Impact of the Rural Electrification Administration 1935-1940.* No. w19743. National Bureau of Economic Research, 2013.

Knittel, Christopher, Douglas Miller and Nicholas Sanders. 2011. "Caution, Drivers! Children Present. Traffic, Pollution and Infant Health." NBER Working Paper #17222.

Laden F, Schwartz J, Speizer FE, Dockery DW. 2006. Reduction in fine particulate air pollution and mortality: extended follow-up of the Harvard six cities study. *Am J Respir Crit Care Med* 173(6):581582.

Lave, Lester and Eugene Seskin. 1972. "Air Pollution, Climate, and Home Heating: Their Effects on U.S. Mortality Rates." *American Journal of Public Health* 62: 909-916.

Lewis, Joshua. (2014). Fertility, Child Health, and the Diffusion of Electricity into the Home, Working Paper - University of Montreal.

Lewis, Joshua, and Edson R. Severnini. (2014). The Value of Rural Electricity: Evidence from the Rollout of the U.S. Power Grid, Working Paper - University of Montreal.

Lipscomb, Molly, Mushfiq A. Mobarak, and Tania Barham. "Development effects of electrification: Evidence from the topographic placement of hydropower plants in Brazil." *American Economic Journal: Applied Economics* 5.2 (2013): 200-231.

Mokyr, Joel. 2000. Why "More Work for Mothers?" Knowledge and Household Behavior, 1870-1945, *Journal of Economic History* 60(1): 1-41.

Nagda, Niren Laxmichand, and Harry E. Rector. *Guidelines for monitoring indoor air quality.* Geomet Technologies, Inc., Rockville, MD, 1986.

Pope CA III, Schwartz J, Ransom MR. 1992. Daily mortality and PM10 pollution in the Utah Valley. *Arch Environ Health.* 47:211217.

Pope, C. Arden, III, Burnett RT, Thun MJ, Calle EE, Krewski D, Ito K, et al. 2002, "Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution." *Journal of the American Medical Association.* 287:11321141.

Pope, C. Arden, III, Douglas L. Rodermund, and Matthew M. Gee. 2007. "Mortality Effects of a Copper Smelter Strike and Reduced Ambient Sulfate Particulate Matter Air Pollution." *Environmental Health Perspectives.* 115(5): 679683.

Ridker, Ronald G., and John A. Henning. "The Determinants of Residential Property Values with Special Reference to Air Pollution," *The Review of Economics and Statistics* (1967): 246-257.

Stern, Arthur C. “History of Air Pollution Legislation in the United States.” *Journal of the Air Pollution Control Association* 32.1 (1982): 44-61.

U.S. Federal Power Commission. (1947). *Steam-Electric Plant Construction Cost and Annual Production Expenses, 1938-1947*. Washington DC: U.S. Federal Power Commission.

U.S. Federal Power Commission. (1948-62). *Steam-Electric Plant Construction Cost and Annual Production Expenses (Annual Supplements)*. Washington DC: U.S. Federal Power Commission.

U.S. Federal Power Commission. (1963). *Principal Electric Power Facilities in the United States* (map). Washington DC: U.S. Federal Power Commission.

United States Bureau of the Census. *Historical statistics of the United States, colonial times to 1970*. No. 93. US Department of Commerce, Bureau of the Census, 1975.

United States Bureau of Mines. *Minerals Yearbook* (various years). Washington: Government Printing Office.

United States Department of Health, Education and Welfare 1958. *Air Pollution Measurements of the National Air Sampling Network: Analyses of Suspended Particulates, 1953-1957*. Public Health Service Publication No 637. Washington: Government Printing Office.

United States General Accountability Office. 2012, *Air Emissions and Electricity Generation at U.S. Power Plants*. Washington: Government Printing Office. http://gao.gov/assets/600/590188.pdf.

Woodruff, Tracey, Lyndsey Darrow, and Jennifer Parker. 2008. “Air Pollution and Postneonatal Infant Mortality in the United States, 1999-2002.” *Environmental Health Perspectives* 116: 110-115.

7 Figures and Tables

Table 1: TSP Concentration by Year

Year	**Number of Counties**	**TSP Concentration** ($\mu g/m^3$)	
		Mean	S.D.
1957	41	141.57	55.00
1958	46	124.63	57.47
1959	64	113.69	60.54
1960	74	110.02	51.05
1961	73	99.93	47.93
1962	73	100.52	45.08

Table 2: The effect of power plant coal consumption on local air quality

Dep Var: TSP Concentration	Year FE + State FE	+State Trend	+Geography + Economy + Hydro Cap	- State Trend +State-Year FE	+ County FE
Panel A. All Power Plants					
Coal Consumption Within 50 Miles	1.1731***	1.1926***	0.6705**	0.6510	0.3860
	(0.2263)	(0.2465)	(0.2790)	(0.4261)	(1.1257)
Counties	75	75	75	75	75
Observations	371	371	371	371	371
R-squared	0.6491	0.6870	0.7737	0.8367	0.9658
Panel B. New Power Plants					
Coal Consumption Within 50 Miles NPP	1.1535***	1.1547***	0.6639**	0.6514	1.5043*
	(0.2178)	(0.2318)	(0.2800)	(0.4513)	(0.8591)
Counties	75	75	75	75	75
Observations	371	371	371	371	371
R-squared	0.6570	0.6930	0.7738	0.8367	0.9674
Sample Means					
TSP Concentration: 1957			141.57		
TSP Concentration: 1962			100.52		
Coal Cons Within 50 miles: 1957			15.67		
Coal Cons Within 50 miles: 1962			20.07		
Coal Cons Within 50 miles (NPP): 1957			15.21		
Coal Cons Within 50 miles (NPP): 1957			18.87		

Notes: Each cell reports the point estimate from a different regression. Geographic covariates include time -varying controls for temperature, precipitation, degree days between 10^{o}C and 29^{o}C and degree days above 29^{o}C, and latitude and longitude interacted with year. Economic covariates include total employment, manufacturing employment, and manufacturing payroll per worker in 1940 interacted with year. Hydro Cap denotes a time-varying control for hydroelectric capacity within 50 miles of the county centroid. Standard errors are clustered at the county-level. ***,**,* denote significance at the 1%, 5%, and 10% level, respectively.

Table 3: The effect of power plant coal consumption on infant mortality

Dep Var: Infant Mortality	Year + County FE	+State Trend	+Geography + Economy	+Elec (1940) +Coal (1927) +Hydro Cap	-State Trend +State-Year FE
Panel A. Annual plant coal consumption					
Coal Consumption Within 50 Miles	0.1683***	0.0908***	0.0669***	0.0531***	0.0832***
	(0.0471)	(0.0151)	(0.0157)	(0.0148)	(0.0198)
Counties	2,197	2,197	2,197	2,197	2,197
Observations	37,349	37,349	37,349	37,349	37,349
R-squared	0.6788	0.7000	0.7139	0.7165	0.7291

Notes: Each cell reports the point estimate from a different regression. Panel A relies on all annual variation in power plant coal consumption, Geographic covariates include time-varying controls for temperature, precipitation, degree days between 10^{o}C and 29^{o}C and degree days above 29^{o}C, and latitude and longitude interacted with year. Economic covariates include total employment, manufacturing employment, and manufacturing payroll per worker in 1940 interacted with year. Hydro Cap denotes a time-varying control for hydroelectric capacity within 50 miles of the county centroid. Elec (1940) and Coal (1927), denote baseline electricity access and coal consumption per square mile, interacted with year. Standard errors are clustered at the county-level. ***,**,* denote significance at the 1%, 5%, and 10% level, respectively.

Table 4: The effect of power plant coal consumption on infant mortality: DD analysis

Dep Var: Infant Mortality	Year + County FE	+State Trend	+Geo +Econ + Elec(1940) +Hydro Cap	-State Trend +State-Year	+ Coal (1927) + County-plant distance
Difference-in-differences					
Plant in Operation × Plant within 25 miles	1.8682**	1.6482***	1.3188***	1.4394***	1.0051***
(Controls: Plants between 25 and 125 miles)	(0.7617)	(0.4908)	(0.4043)	(0.4010)	(0.3794)
Plant in Operation × Plant within 25 miles	1.6843**	1.3467***	0.9574**	1.1073***	0.8087**
(Controls: Plants between 25 and 100 miles)	(0.7452)	(0.4475)	(0.3883)	(0.3857)	(0.3801)
Plant in Operation × Plant within 25 miles	1.8012**	1.3423***	1.0512**	1.1704***	0.9378**
(Controls: Plants between 25 and 75 miles)	(0.7517)	(0.4580)	(0.4268)	(0.4340)	(0.4158)
Plant in Operation × Plant within 25 miles	1.7164**	1.1662**	0.7324*	0.8680*	0.9119*
(Controls: Plants between 25 and 50 miles)	(0.7043)	(0.5018)	(0.4373)	(0.4433)	(0.5191)

Notes: Each cell reports the point estimate from a different regression. The table reports the difference-in-differences estimate. Geographic covariates include time-varying controls for temperature, precipitation, degree days between 10^{o}C and 29^{o}C and degree days above 29^{o}C, and latitude and longitude interacted with year. Economic covariates include total employment, manufacturing employment, and manufacturing payroll per worker in 1940 interacted with year. Hydro Cap denotes a time-varying control for hydroelectric capacity within 50 miles of the county centroid. Elec (1940) and Coal (1927), denote baseline electricity access and coal consumption per square mile, interacted with year. Standard errors are clustered at the county-level. ***,**,* denote significance at the 1%, 5%, and 10% level, respectively.

Table 5: The effect of power plant coal consumption on infant mortality, by pollution level

Dep Var: Infant Mortality	Year + County FE	+State Trend	+Geography + Economy	+Elec (1940) +Coal (1927) +Hydro Cap	-State Trend +State-Year FE
Panel A. Annual plant coal consumption					
Coal Consumption Within 50 Miles × 1-5 (100,000 Tons of Coal)	0.0956 (0.1161)	0.1314 (0.0848)	0.1585** (0.0805)	0.1314 (0.0804)	0.1383* (0.0839)
Coal Consumption Within 50 Miles × 5-20 (100,000 Tons of Coal)	0.1647*** (0.0517)	0.1095*** (0.0358)	0.0741** (0.0356)	0.0738** (0.0350)	0.1105*** (0.0378)
Coal Consumption Within 50 Miles × 20-40 (100,000 Tons of Coal)	0.1825*** (0.0487)	0.1019*** (0.0294)	0.0610** (0.0280)	0.0552** (0.0266)	0.1013*** (0.0299)
Coal Consumption Within 50 Miles × 40-60 (100,000 Tons of Coal)	0.1794*** (0.0407)	0.1005*** (0.0226)	0.0637*** (0.0213)	0.0583*** (0.0202)	0.0918*** (0.0236)
Coal Consumption Within 50 Miles × 60-80 (100,000 Tons of Coal)	0.1776*** (0.0458)	0.0973*** (0.0179)	0.0680*** (0.0188)	0.0557*** (0.0177)	0.0902*** (0.0215)
Coal Consumption Within 50 Miles × 80-130 (100,000 Tons of Coal)	0.1319*** (0.0316)	0.0809*** (0.0158)	0.0598*** (0.0171)	0.0478*** (0.0162)	0.0778*** (0.0212)
Counties	2,197	2,197	2,197	2,197	2,197
Observations	37,349	37,349	37,349	37,349	37,349
R-squared	0.6790	0.7000	0.7139	0.7171	0.7292

Notes: Each column reports the point estimates from a different regression. Each row reports the interaction of the term $Emissions_{ct}$ with baseline coal consumption in 1927. Panel A relies on all annual variation in power plant coal consumption. Geographic covariates include time-varying controls for temperature, precipitation, degree days between 10^oC and 29^oC and degree days above 29^oC, and latitude and longitude interacted with year. Economic covariates include total employment, manufacturing employment, and manufacturing payroll per worker in 1940 interacted with year. Hydro Cap denotes a time-varying control for hydroelectric capacity within 50 miles of the county centroid. Elec (1940) and Coal (1927), denote baseline electricity access and coal consumption per square mile, interacted with year. Standard errors are clustered at the county-level. ***,**,* denote significance at the 1%, 5%, and 10% level, respectively.

Table 6: Effect of distance to nearest large steam power plants on rental prices and wages

	Year + County FE	+State Trend	+Geography + Economy	+Elec (1940) +Coal (1927) +Hydro Cap	-State Trend +State-Year FE
Panel A. Dep Var: Ln(Median Rent)					
DistPP50Steam	0.0070***	0.0032**	-0.0004	-0.0004	0.0019
	(0.0019)	(0.0015)	(0.0015)	(0.0015)	(0.0016)
Counties	1,321	1,321	1,321	1,321	1,321
Observations	3963	3963	3963	3963	3963
R-squared	0.9260	0.9499	0.9580	0.9580	0.9608
Panel B. Dep Var: Ln(Wage)					
DistPP50Steam	0.0021	-0.0010	-0.0016	-0.0016	-0.0023
	(0.0018)	(0.0021)	(0.0021)	(0.0021)	(0.0024)
Counties	1,049	1,049	1,049	1,049	1,049
Observations	3,147	3,147	3,147	3,147	3,147
R-squared	0.8896	0.9004	0.9013	0.9013	0.9030

Notes: Each cell reports the point estimate from a different regression. The term DistPP50Steam denotes county-centroid distance to nearest large steam plant (>50mw). Geographic covariates include time-varying controls for temperature, precipitation, degree days between 10^oC and 29^oC and degree days above 29^oC, and latitude and longitude interacted with year. Economic covariates include total employment, manufacturing employment, and manufacturing payroll per worker in 1940 interacted with year. Hydro Cap denotes a time-varying control for hydroelectric capacity within 50 miles of the county centroid. Elec (1940) and Coal (1927), denote baseline electricity access and coal consumption per square mile, interacted with year. Standard errors are clustered at the county-level. ***,**,* denote significance at the 1%, 5%, and 10% level, respectively.

Table 7: Effect of distance to nearest large steam power plants on rental prices, by baseline electricity access (PHHL1940) and baseline pollution (CCSM1927)

Dep Var: Ln(Median Rent)	Year + County FE	+State Trend	+Geography + Economy	+Elec (1940) +Coal (1927) +Hydro Cap	-State Trend +State-Year FE
DistPP50Steam x L-PHHL1940 x H-CCSM1927	0.0461***	0.0290***	0.0242***	0.0243***	0.0264***
	(0.0071)	(0.0086)	(0.0082)	(0.0082)	(0.0084)
DistPP50Steam x L-PHHL1940 x M-CCSM1927	0.0375***	0.0180***	0.0141***	0.0141***	0.0123***
	(0.0042)	(0.0041)	(0.0039)	(0.0039)	(0.0040)
DistPP50Steam x L-PHHL1940 x L-CCSM1927	0.0241***	0.0096***	0.0037	0.0037	0.0059*
	(0.0039)	(0.0032)	(0.0031)	(0.0031)	(0.0034)
DistPP50Steam x M-PHHL1940 x H-CCSM1927	0.0188***	0.0226***	0.0201***	0.0201***	0.0214***
	(0.0058)	(0.0073)	(0.0069)	(0.0069)	(0.0071)
DistPP50Steam x M-PHHL1940 x M-CCSM1927	0.0029	0.0038	0.0016	0.0016	0.0007
	(0.0032)	(0.0023)	(0.0022)	(0.0022)	(0.0022)
DistPP50Steam x M-PHHL1940 x L-CCSM1927	0.0028	0.0006	-0.0047*	-0.0047*	-0.0017
	(0.0022)	(0.0024)	(0.0025)	(0.0025)	(0.0034)
DistPP50Steam x H-PHHL1940 x H-CCSM1927	-0.0264***	-0.0102	-0.0101	-0.0101	-0.0093
	(0.0089)	(0.0073)	(0.0067)	(0.0067)	(0.0068)
DistPP50Steam x H-PHHL1940 x M-CCSM1927	-0.0225***	-0.0127***	-0.0164***	-0.0164***	-0.0168***
	(0.0034)	(0.0037)	(0.0036)	(0.0036)	(0.0037)
DistPP50Steam x H-PHHL1940 x L-CCSM1927	-0.0078**	-0.0105**	-0.0127***	-0.0127***	-0.0098*
	(0.0033)	(0.0045)	(0.0049)	(0.0049)	(0.0051)
Counties	1,321	1,321	1,321	1,321	1,321
Observations	3963	3963	3963	3963	3963
R-squared	0.9375	0.9527	0.9602	0.9603	0.9628

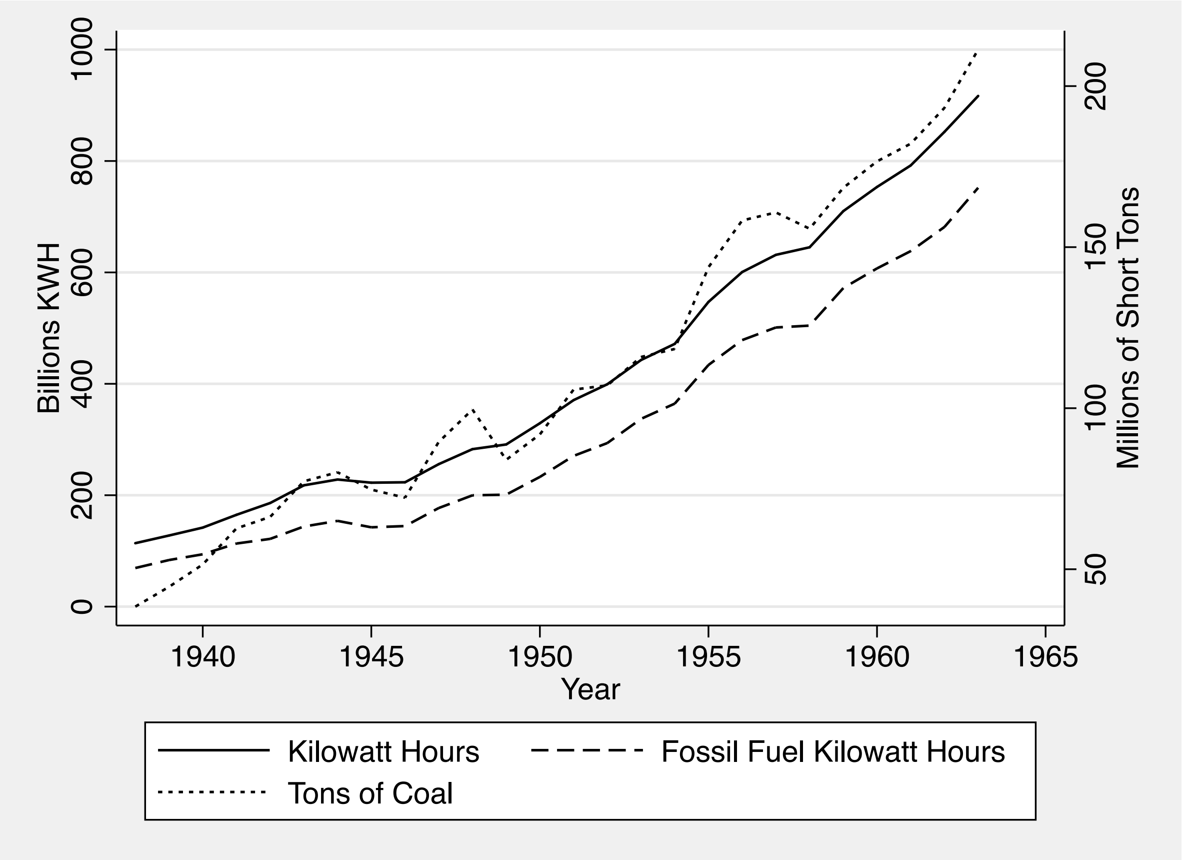
Notes: Each column reports the point estimates from a different regression. Each row reports the interaction of the term $Emissions_{ct}$ with baseline electricity access (PHHL1940) and baseline coal consumption (CCSM1927)). Geographic covariates include time-varying controls for temperature, precipitation, degree days between 10^{o}C and 29^{o}C above 29^{o}C, and latitude and longitude interacted with year. Economic covariates include total employment, manufacturing employment, and manufacturing payroll per worker in 1940 interacted with year. Hydro Cap denotes a time-varying control for hydroelectric capacity within 50 miles of the county centroid. Elec (1940) and Coal (1927), denote baseline electricity access and coal consumption per square mile, interacted with year. Standard errors are clustered at the county-level. ***,**,* denote significance at the 1%, 5%, and 10% level, respectively.

Table 8: The effect of distance to large steam power plants on wages, by baseline electricity access (PHHL1940) and baseline pollution (CCSM1927)

Dep Var: Ln(Wage)	Year + County FE	+State Trend	+Geography + Economy	+Elec (1940) +Coal (1927) +Hydro Cap	-State Trend +State-Year FE
DistPP50Steam x L-PHHL1940 x H-CCSM1927	0.0098	-0.0045	-0.0072	-0.0075	-0.0051
	(0.0088)	(0.0089)	(0.0090)	(0.0090)	(0.0097)
DistPP50Steam x L-PHHL1940 x M-CCSM1927	0.0125*	-0.0005	-0.0023	-0.0024	-0.0022
	(0.0066)	(0.0071)	(0.0071)	(0.0071)	(0.0072)
DistPP50Steam x L-PHHL1940 x L-CCSM1927	0.0109**	-0.0004	-0.0006	-0.0006	-0.0024
	(0.0044)	(0.0052)	(0.0052)	(0.0052)	(0.0055)
DistPP50Steam x M-PHHL1940 x H-CCSM1927	-0.0010	0.0035	0.0039	0.0039	0.0046
	(0.0091)	(0.0074)	(0.0072)	(0.0072)	(0.0074)
DistPP50Steam x M-PHHL1940 x M-CCSM1927	-0.0033	-0.0059	-0.0067	-0.0069	-0.0066
	(0.0036)	(0.0049)	(0.0049)	(0.0049)	(0.0049)
DistPP50Steam x M-PHHL1940 x L-CCSM1927	0.0001	0.0008	-0.0003	-0.0002	-0.0027
	(0.0024)	(0.0031)	(0.0034)	(0.0034)	(0.0045)
DistPP50Steam x H-PHHL1940 x H-CCSM1927	-0.0064	0.0003	0.0030	0.0031	0.0033
	(0.0048)	(0.0060)	(0.0058)	(0.0058)	(0.0059)
DistPP50Steam x H-PHHL1940 x M-CCSM1927	-0.0029	-0.0026	-0.0029	-0.0030	-0.0017
	(0.0039)	(0.0056)	(0.0055)	(0.0055)	(0.0058)
DistPP50Steam x H-PHHL1940 x L-CCSM1927	-0.0014	-0.0005	-0.0012	-0.0011	-0.0028
	(0.0025)	(0.0027)	(0.0030)	(0.0030)	(0.0040)
Counties	1,049	1,049	1,049	1,049	1,049
Observations	3,147	3,147	3,147	3,147	3,147
R-squared	0.8913	0.9005	0.9015	0.9015	0.9032

Notes: Each column reports the point estimates from a different regression. Each row reports the interaction of the term $Emissions_{ct}$ with baseline electricity access (PHHL1940) and baseline coal consumption (CCSM1927)). Geographic covariates include time-varying controls for temperature, precipitation, degree days between 10^{o}C and 29^{o}C and degree days above 29^{o}C, and latitude and longitude interacted with year. Economic covariates include total employment, manufacturing employment, and manufacturing payroll per worker in 1940 interacted with year. Hydro Cap denotes a time-varying control for hydroelectric capacity within 50 miles of the county centroid. Elec (1940) and Coal (1927), denote baseline electricity access and coal consumption per square mile, interacted with year. Standard errors are clustered at the county-level. ***,**,* denote significance at the 1%, 5%, and 10% level, respectively.

Figure 1: Trends in Electricity Generation



Notes: Data are from Gartner et al, *Historical Statistics of the United States* (2006). Table Db218-227. Electric utilities-power generation and fossil fuel consumption, by energy source: 1920-2000.

Figure 2: U.S. Thermal Power Plant Capacity, 1940-1960

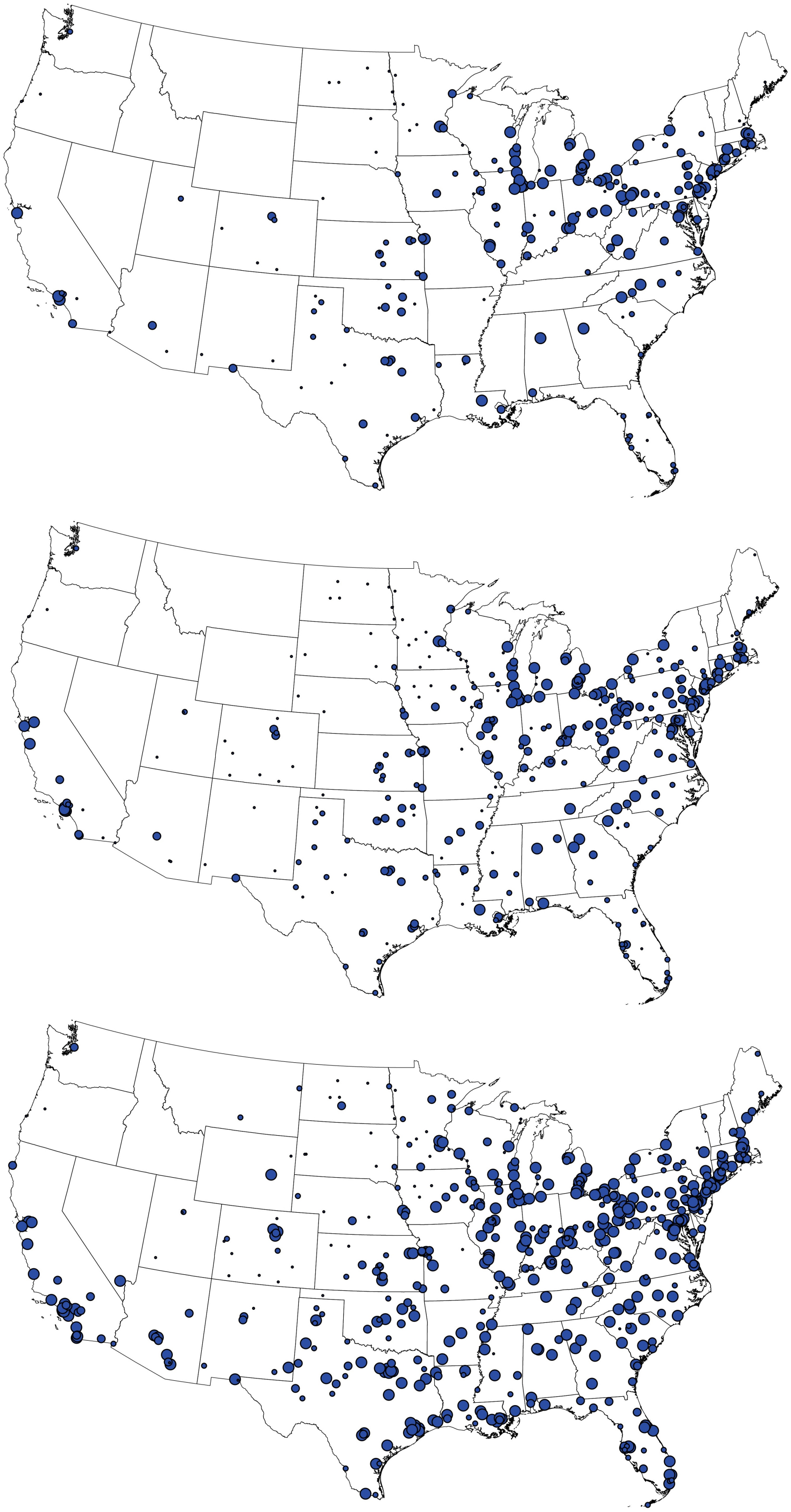
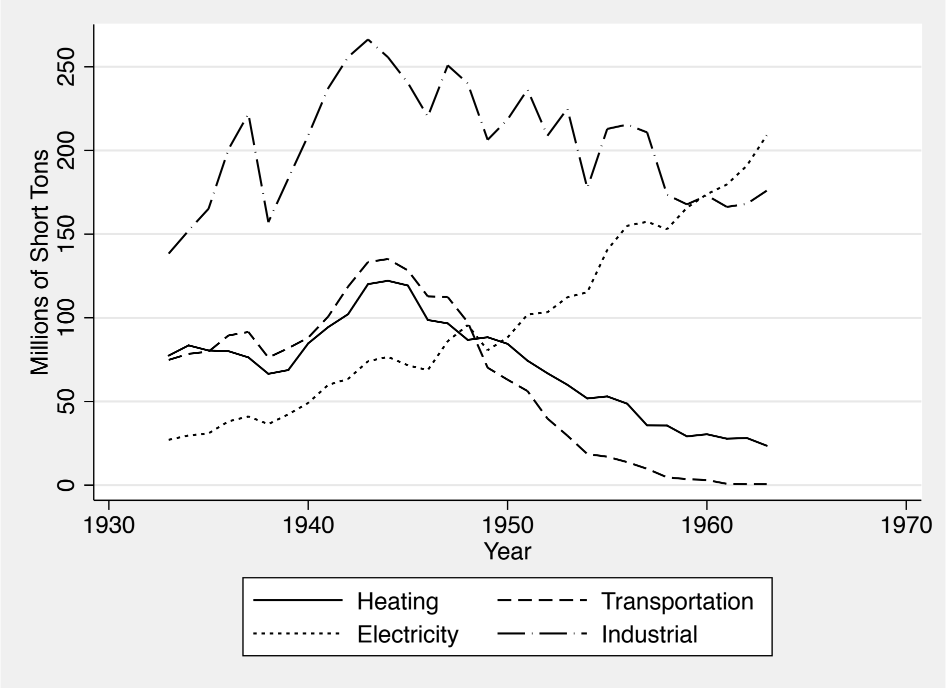
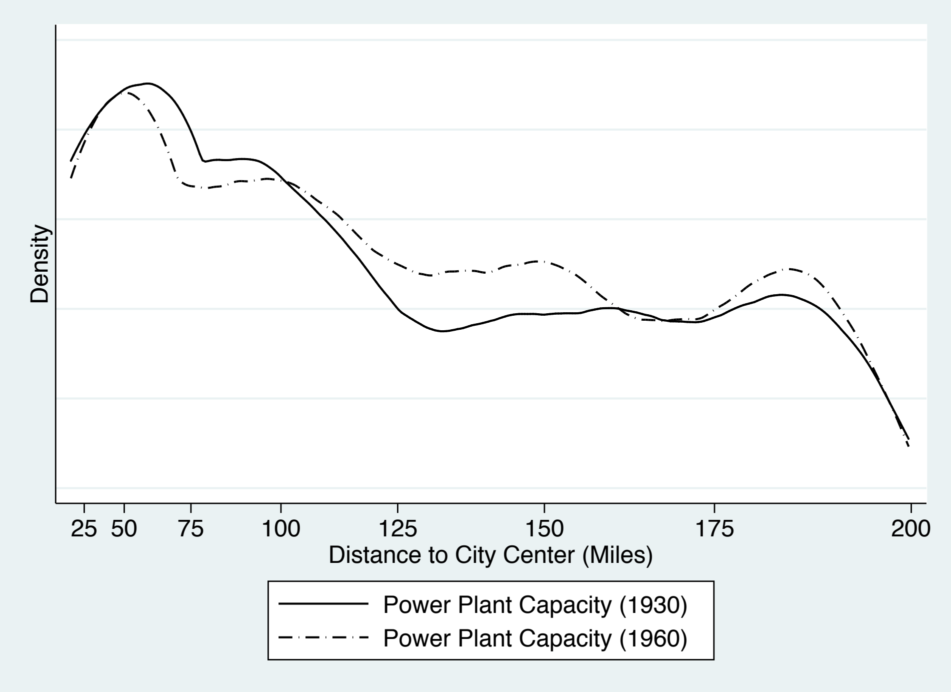


Figure 3: Coal Consumption, by Source



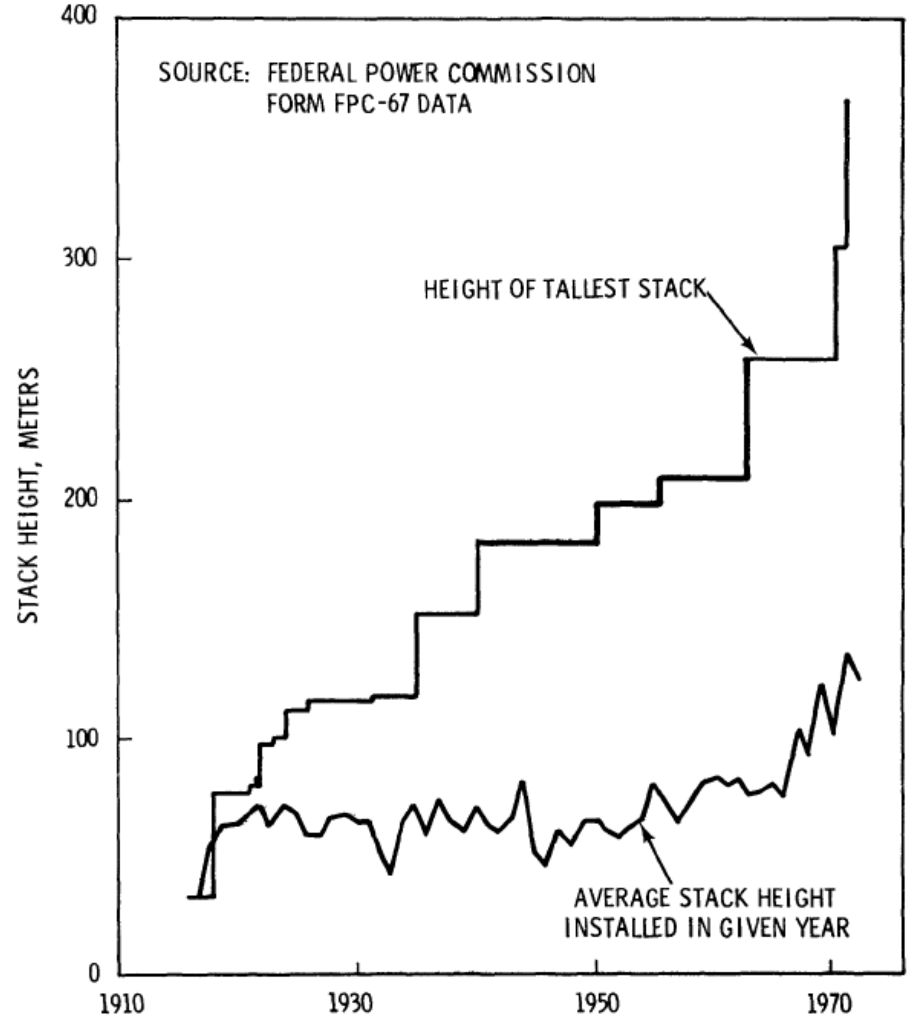
Notes: Data are from United States Bureau of Mines, Minerals Yearbook (various years).

Figure 4: Distribution of Fossil-Fuel Capacity



Notes: This figure report the density of fossil-fuel capacity within 200 miles of the city-centroid for the 50 largest cities in the US.

Figure 5: Thermal Power Plant Smoke-Stack Height



Source: Hales (1976) Figure 3, p.10.

Figure 6: Counties with TSP Monitors

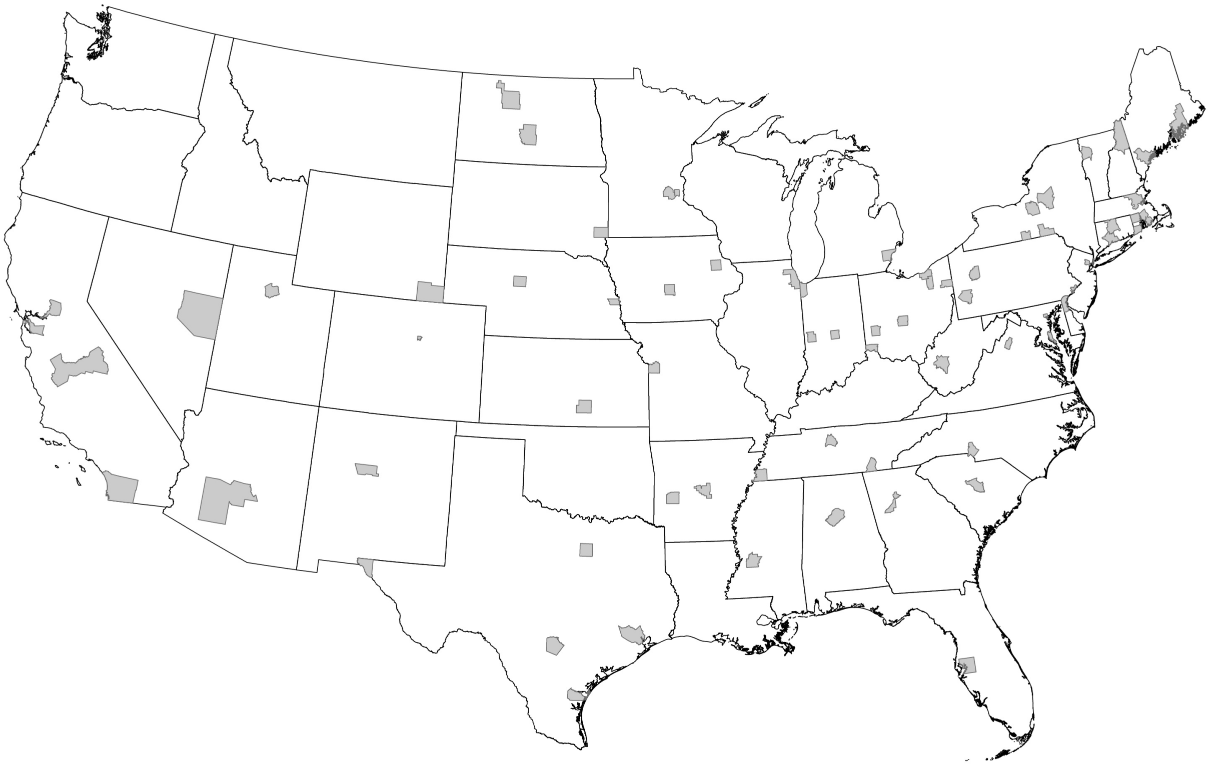


Figure 7: Counties Included in the Infant Mortality Regressions

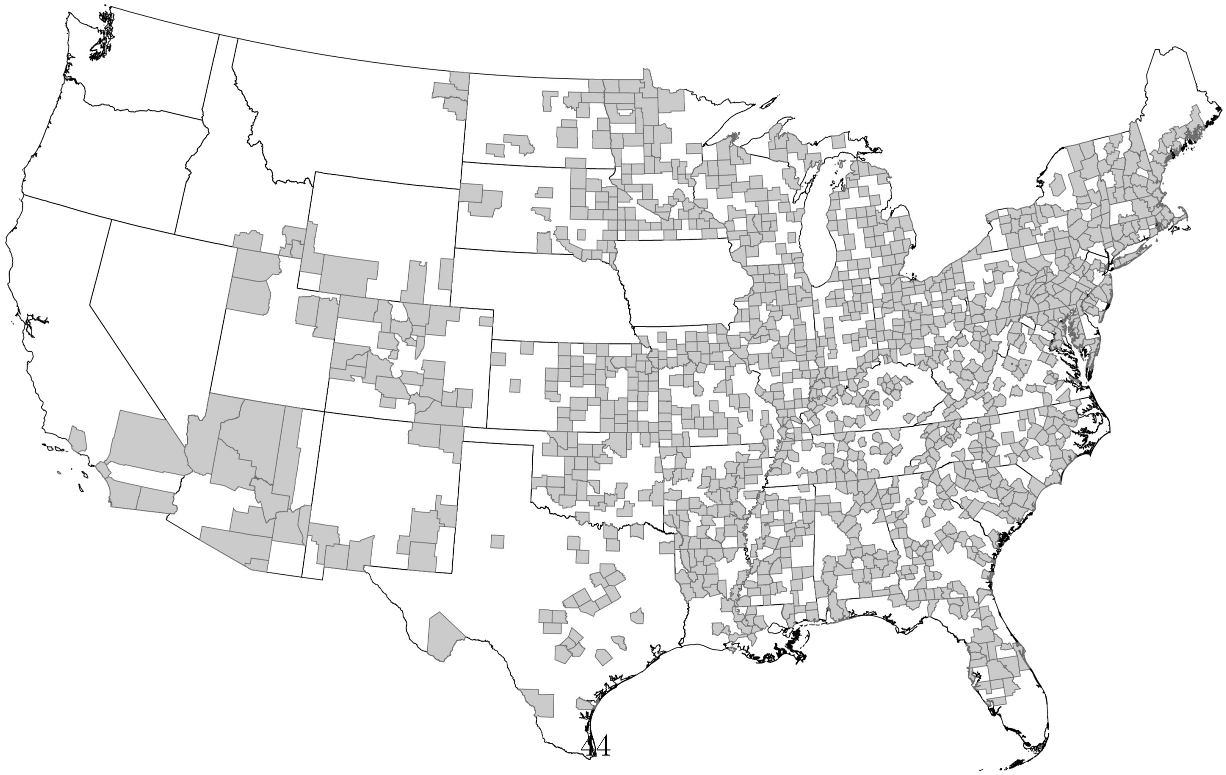
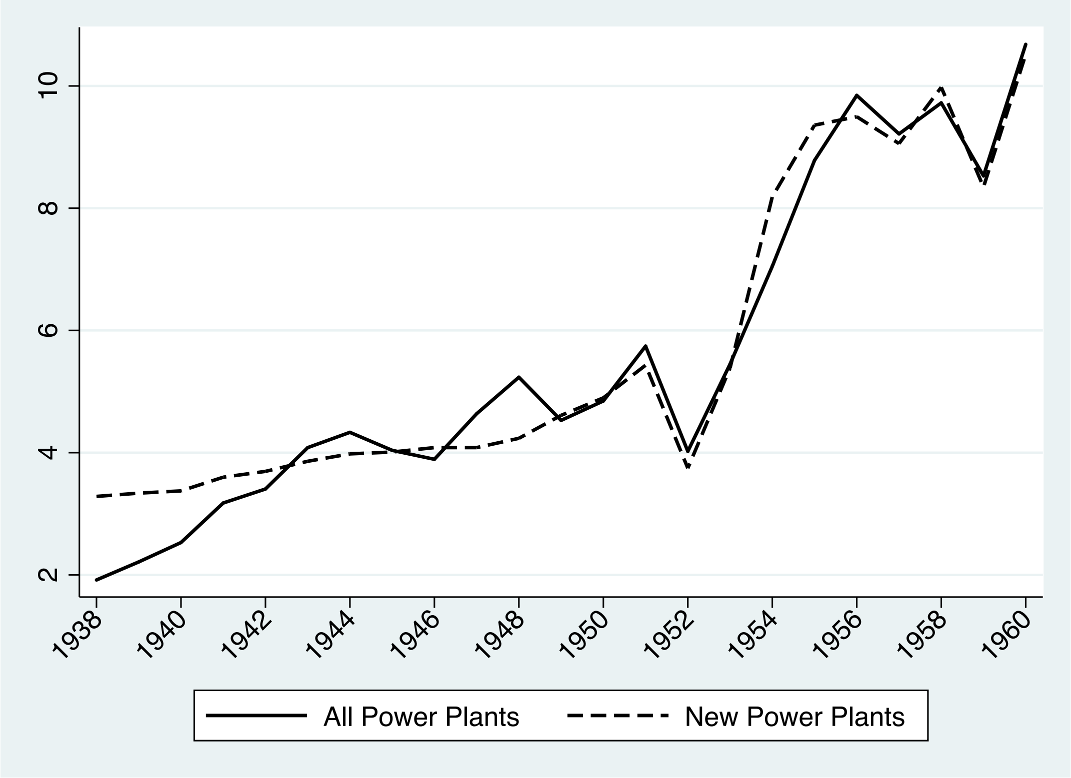
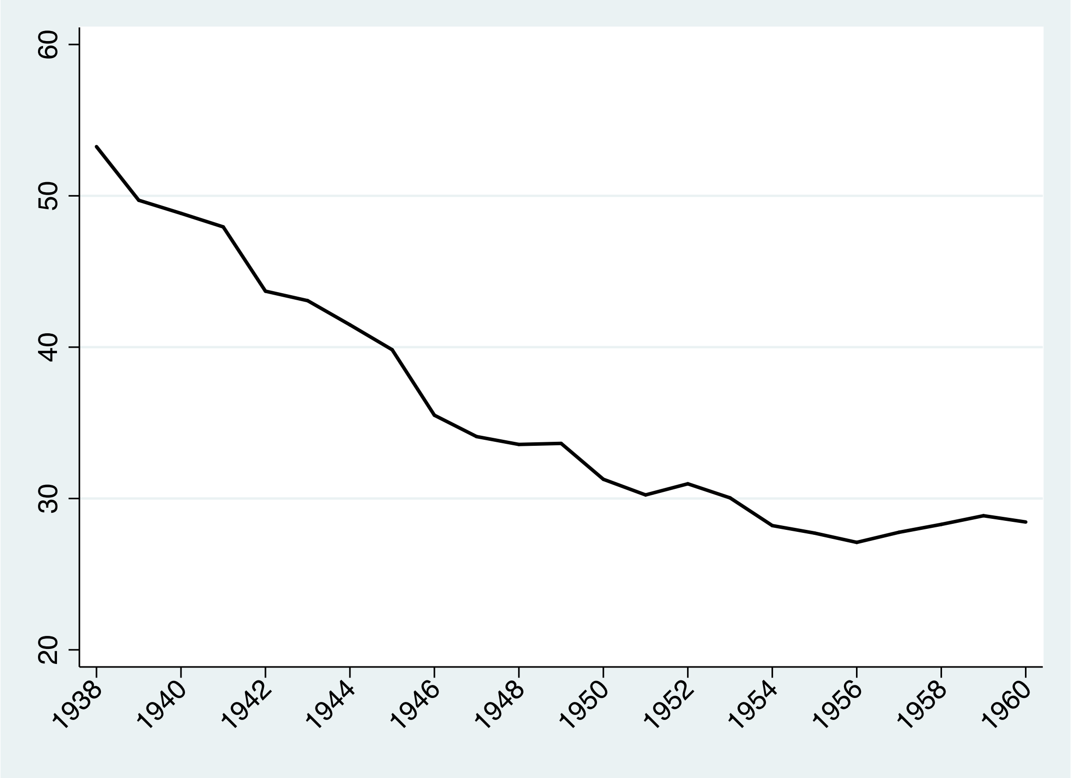


Figure 8: Trends Power Plant Coal Consumption, 1938-1960



Notes: The figure reports the total coal consumption by electric utilities (100,000s of short tons) with 50 miles of county-centroid.

Figure 9: Trends in Infant Mortality, 1938-1960



Notes: The figure reports infant mortality (per 1,000 births).

A Appendix

A.1 Additional Figures and Tables

Table A.1: TSP Concentration in Various Years

Location	Time	TSP	Source
Chicago	1912-1913	760	Eisenbud (1978)
14 Large US Cities	1931-1933, Winter	510	Ives et al (1936)
US Urban Stations	1953-1957	163	U.S. Department of Health, Education and Welfare (1958)
8 of 14 Large US Cities	1954	214	U.S. Department of Health, Education and Welfare (1958)
US Urban Stations	1960	118	Lave and Seskin (1972)
14 Large US Cities	1960	143	EPA data
US National Average	1990	60	Chay and Greenstone (2003a)
58 Chinese Cities	1980-1993	538	Almond et al (2009)
Worldwide	1999	18% of urban pop > 240	Cohen et al (2004)

Notes: The original measurements were in TSP for all of the sources except for Cohen et al (2004). Cohen et al , Figure 17.3 (World), indicates that 18% of the urban population lived in locations where the PM10 was greater than 100. We translated the PM10 values to TSP using the following formula: PM10/0.417, where 0.417 is the empirical ratio of PM10 to TSP in their world data (Table 17.4). The estimate for 1990 is from Chay and Greenstone (2003a), Figure 1. EPA data are authors calculations based on EPA dataset for 1960.

Table A.2: Municipal Smoke Abatement Legislation Prior to 1930

Decade	Cities Passing Legislation
1880-1890	Chicago, Cincinnati
1890-1900	Cleveland, Pittsburgh, St. Paul
1900-1910	Akron, Baltimore, Boston, Buffalo, Dayton, Detroit, Indianapolis, Los Angeles, Milwaukee, Minneapolis, New York, Newark, Philadelphia, Rochester, St. Louis, Springfield (MA), Syracuse, Washington
1910-1920	Albany County (NY), Atlanta, Birmingham, Columbus, Denver, Des Moines, Duluth, Flint, Hartford, Jersey City, Kansas City, Louisville, Lowell, Nashville, Portland (OR), Providence, Richmond, Toledo
1920-1930	Cedar Rapids, East Cleveland, Erie County (NY), Harrisburg, Grand Rapids, Lansing, Omaha, Salt Lake City, San Francisco, Seattle, Sioux City, Wheeling

Source: Stern 1982, Table III, p. 45.

Table A.3: Housing Market Characteristics, by Initial Electricity Access (PHHL1940) and Initial Pollution Levels (CCSM1927)

	Number of Counties	Total Population (1000s)	Median Dwelling Value ($1990)	Median Dwelling Rent ($1990)	Coal Cons. Within 50 Miles	Coal Cons. Within 50 Miles	Hydro Capacity Within 50 Miles
Panel A. 1940							
L-PHHL1940 x H-CCSM1927	92	1,915	10,303	57	90	125	92
L-PHHL1940 x M-CCSM1927	129	2,682	11,750	51	36	54	102
L-PHHL1940 x L-CCSM1927	141	3,257	9,378	52	5	4	4
M-PHHL1940 x H-CCSM1927	141	2,915	13,082	86	288	396	33
M-PHHL1940 x M-CCSM1927	143	3,562	14,976	91	105	182	62
M-PHHL1940 x L-CCSM1927	106	2,376	12,491	96	26	22	13
H-PHHL1940 x H-CCSM1927	339	40,331	25,037	160	2,415	3,154	58
H-PHHL1940 x M-CCSM1927	87	4,560	21,293	145	88	137	68
H-PHHL1940 x L-CCSM1927	30	2,011	19,868	157	2	2	35
Total	1,208	63,610	16,583	104	3,056	4,076	53
Panel B. Change (1960-1940)							
L-PHHL1940 x H-CCSM1927	92	-186	15,998	127	1,138	968	51
L-PHHL1940 x M-CCSM1927	129	58	16,057	122	624	544	82
L-PHHL1940 x L-CCSM1927	141	-276	17,945	120	83	85	11
M-PHHL1940 x H-CCSM1927	141	150	17,542	152	1,967	1,710	14
M-PHHL1940 x M-CCSM1927	143	596	17,795	143	733	552	40
M-PHHL1940 x L-CCSM1927	106	817	21,813	153	41	56	14
H-PHHL1940 x H-CCSM1927	339	14,984	20,719	141	4,903	4,434	8
H-PHHL1940 x M-CCSM1927	87	1,872	22,061	141	343	265	31
H-PHHL1940 x L-CCSM1927	30	3,069	27,026	132	16	14	18
Total	1,208	21,081	19,170	138	9,847	8,628	26

Table A.4: The effect of power plant coal consumption on rental prices and wages

	Year + County FE	+State Trend	+Geography + Economy	+Elec (1940) +Coal (1927) +Hydro Cap	-State Trend +State-Year FE
Dep var: Ln(Median Rent)					
Coal Consumption Within 50 Miles	-0.0024***	-0.0008	-0.0002	-0.0002	-0.0002
	(0.0006)	(0.0006)	(0.0005)	(0.0005)	(0.0005)
Counties	1,321	1,321	1,321	1,321	1,321
Observations	3963	3963	3963	3963	3963
R-squared	0.9254	0.9498	0.9580	0.9580	0.9607
Panel B. Ln(Wage)					
Coal Consumption Within 50 Miles	-0.0003	-0.0001	-0.0001	-0.0001	-0.0003
	(0.0006)	(0.0005)	(0.0006)	(0.0006)	(0.0006)
Counties	1,049	1,049	1,049	1,049	1,049
Observations	3,147	3,147	3,147	3,147	3,147
R-squared	0.8895	0.9004	0.9013	0.9013	0.9030

Notes: Each column reports the point estimates from a different regression. Each row reports the interaction of the term $Emissions_{ct}$ with baseline coal consumption in 1927. Panel A relies on all annual variation in power plant coal consumption, Panel B relies on annual variation in coal consumption associated with the construction of new power plants. Geographic covariates include time-varying controls for temperature, precipitation, degree days between 10^{o}C and 29^{o}C and degree days above 29^{o}C, and latitude and longitude interacted with year. Economic covariates include total employment, manufacturing employment, and manufacturing payroll per worker in 1940 interacted with year. Hydro Cap denotes a time-varying control for hydroelectric capacity within 50 miles of the county centroid. Elec (1940) and Coal (1927), denote baseline electricity access and coal consumption per square mile, interacted with year. Standard errors are clustered at the county-level. ***,**,* denote significance at the 1%, 5%, and 10% level, respectively.

Table A.5: The effect of power plant coal consumption on rental prices and wages, by baseline electricity access (PHHL1940) and baseline pollution (CCSM1927)

	Year + County FE	+State Trend	+Geography + Economy	+Elec (1940) +Coal (1927) +Hydro Cap	-State Trend +State-Year FE
Dep var: Ln(Median Rent)					
CC50Miles x L-PHHL1940 x H-CCSM1927	0.0030**	0.0020	0.0018	0.0018	0.0020
	(0.0012)	(0.0014)	(0.0013)	(0.0013)	(0.0013)
CC50Miles x L-PHHL1940 x M-CCSM1927	0.0084***	-0.0017	-0.0010	-0.0010	0.0022
	(0.0027)	(0.0025)	(0.0025)	(0.0025)	(0.0026)
CC50Miles x L-PHHL1940 x L-CCSM1927	0.0151**	-0.0010	0.0027	0.0027	0.0048
	(0.0072)	(0.0074)	(0.0074)	(0.0074)	(0.0073)
CC50Miles x M-PHHL1940 x H-CCSM1927	0.0012	0.0019**	0.0015*	0.0015*	0.0013
	(0.0009)	(0.0009)	(0.0009)	(0.0009)	(0.0009)
CC50Miles x M-PHHL1940 x M-CCSM1927	0.0051***	-0.0025	-0.0019	-0.0019	0.0001
	(0.0019)	(0.0019)	(0.0019)	(0.0019)	(0.0020)
CC50Miles x M-PHHL1940 x L-CCSM1927	0.0139	0.0001	0.0076	0.0076	0.0045
	(0.0199)	(0.0142)	(0.0141)	(0.0141)	(0.0142)
CC50Miles x H-PHHL1940 x H-CCSM1927	-0.0073***	-0.0026***	-0.0015**	-0.0015**	-0.0020***
	(0.0010)	(0.0009)	(0.0007)	(0.0007)	(0.0007)
CC50Miles x H-PHHL1940 x M-CCSM1927	-0.0077*	-0.0098***	-0.0070**	-0.0070**	-0.0059**
	(0.0041)	(0.0031)	(0.0029)	(0.0029)	(0.0027)
CC50Miles x H-PHHL1940 x L-CCSM1927	0.0041	-0.0390***	-0.0267***	-0.0267***	-0.0285***
	(0.0105)	(0.0110)	(0.0097)	(0.0097)	(0.0095)
Dep var: Ln(Wage)					
CC50Miles x L-PHHL1940 x H-CCSM1927	0.0022	0.0011	0.0013	0.0012	0.0009
	(0.0025)	(0.0025)	(0.0025)	(0.0025)	(0.0027)
CC50Miles x L-PHHL1940 x M-CCSM1927	0.0069**	0.0047	0.0049	0.0046	0.0041
	(0.0033)	(0.0038)	(0.0038)	(0.0038)	(0.0039)
CC50Miles x L-PHHL1940 x L-CCSM1927	0.0114**	0.0008	0.0011	0.0012	0.0020
	(0.0055)	(0.0064)	(0.0066)	(0.0066)	(0.0057)
CC50Miles x M-PHHL1940 x H-CCSM1927	0.0008	0.0006	0.0003	0.0003	0.0003
	(0.0010)	(0.0009)	(0.0010)	(0.0009)	(0.0009)
CC50Miles x M-PHHL1940 x M-CCSM1927	-0.0009	-0.0012	-0.0008	-0.0010	-0.0019
	(0.0031)	(0.0019)	(0.0020)	(0.0020)	(0.0021)
CC50Miles x M-PHHL1940 x L-CCSM1927	0.0172	0.0017	0.0032	0.0030	0.0032
	(0.0210)	(0.0170)	(0.0169)	(0.0169)	(0.0179)
CC50Miles x H-PHHL1940 x H-CCSM1927	-0.0014***	-0.0008*	-0.0009	-0.0009	-0.0009
	(0.0005)	(0.0005)	(0.0005)	(0.0005)	(0.0006)
CC50Miles x H-PHHL1940 x M-CCSM1927	0.0009	0.0018	0.0014	0.0015	0.0013
	(0.0025)	(0.0030)	(0.0029)	(0.0029)	(0.0029)
CC50Miles x H-PHHL1940 x L-CCSM1927	0.0200***	-0.0077	-0.0089	-0.0089	-0.0065
	(0.0067)	(0.0099)	(0.0098)	(0.0098)	(0.0093)

Notes: Each column reports the point estimates from a different regression. Each row reports the interaction of the term $Emissions_{ct}$ with baseline coal consumption in 1927. Panel A relies on all annual variation in power plant coal consumption, Panel B relies on annual variation in coal consumption associated with the construction of new power plants. Geographic covariates include time-varying controls for temperature, precipitation, degree days between 10^{o}C and 29^{o}C and degree days above 29^{o}C, and latitude and longitude interacted with year. Economic covariates include total employment, manufacturing employment, and manufacturing payroll per worker in 1940 interacted with year. Hydro Cap denotes a time-varying control for hydroelectric capacity within 50 miles of the county centroid. Elec (1940) and Coal (1927), denote baseline electricity access and coal consumption per square mile, interacted with year. Standard errors are clustered at the county-level. ***,**,* denote significance at the 1%, 5%, and 10% level, respectively.