Benefits and Costs of Electricity Pre-Clean Air Act

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Abstract

This paper exploits the historical expansion of U.S. thermal power generation between 1940 and 1960 to study the costs and benefits associated with steam electricity. We analyze three related issues. First, we estimate the direct health costs related to exposure to local thermal emissions, and find that pollution driven by the burning of coal leads to an increase in infant mortality rates in that period. Second, we investigate how these costs of pollution compare to the variety of benefits afforded by local electricity access, and provide evidence that housing prices are not systematically affected by access to new thermal power, suggesting that the benefits of local electricity access roughly offset the pollution costs. Third, we examine how these tradeoffs evolve along the process of development. At low household electrification rates, access to new thermal power appears to have positive effects on housing prices, indicating that the benefits of greater electricity access may exceed the pollution costs. At high household electrification rates, however, we find negative effects. These results suggest that benefits of thermal power may diminish with economic development, as a greater fraction of the population gain access to electricity. Given the longevity of power plants, policymakers must anticipate these changes in household preferences when choosing the energy mix in developing countries.

1 Introduction

China and India are opening thermal power plants at an extremely rapid pace. Many have little or no emission controls. This situation is similar to the U.S. in the age of electrification, particularly the period from the 1940s-1960s, when transmission lines and economies of scale allowed utilities to build large generation plants outside of cities, and generation plants did nothing to limit their emissions beyond building moderately tall smokestacks.

The expansion of thermal generating capacity offers both benefits and costs to local communities. On the one hand, electricity offers a range of benefits to households (Lewis and Severnini, 2014) including access to lighting and electrical appliances for home production (Lewis, 2014a, 2014b). Similarly, electricity has been linked to increases in firm output and productivity and employment (Allcott, Collard-Wexler, and O'Connell, 2014; Hanlon, 2014; Kitchens and Fishback, 2014; Severnini, 2014). However, these benefits may be offset by the health costs associated with increases in fossil fuel emissions (Stieb et al., 2012; Currie et al., 2013)[1]. It is essential to have a clear understanding of these tradeoffs in order to make informed energy investment decisions.

This paper exploits the historical expansion of U.S. thermal generation between 1940 and 1960 to study the costs and benefits associated with thermal power. We examine three related questions: 1) What are the direct health costs associated with exposure to local thermal emissions? 2) How do these costs compare to the variety of benefits afforded by local electricity access? and 3) How do these tradeoffs evolve along the process of development?

To study the impact of thermal emissions on health, we exploit annual variation in coal consumption and production by steam power plants for the period 1938 to 1949. We estimate fixed effects models relating contemporaneous changes in local emissions to changes in infant mortality rates. These results suggests that pollution driven by the burning of coal leads to an increase in infant mortality rates in that period.

[1] In an influential study, Chay and Greenstone (2003) show that a 1-percent reduction in total suspended particulates (TSP) in the early 1980s in the U.S. results in a 0.35-percent decline in the infant mortality rate at the county level.

Next, we adopt a hedonic approach to evaluate the net benefits of new thermal power capacity on housing prices - rents and home values. We rely on decadal changes in distances to steam power plants arising from the construction of new facilities to identify those net benefits. We focus on large steam power plants - with at least 50 MW of capacity - to limit concerns of endogenous site choice[2]. The estimates for housing prices are small and insignificant, suggesting that the benefits of local electricity access roughly offset the pollution costs.

Lastly, we employ a final strategy to disentangle the net benefits and net costs of new thermal power plants, and shed light on how these tradeoffs might evolve along the process of development. We estimate hedonic regressions of housing prices on distance to steam power plants, interacting distances with nine bins conveying information about initial household electricity access and baseline levels of pollution[3]. At low levels of thermal generation the net benefits should be positive, as the benefits of greater electricity access should exceed the pollution costs. As thermal generation capacity expands, the benefits will diminish, as there is less scope to expand electricity access (see figure 1). We find empirical support for this relationship: access to thermal generation has positive effects on housing prices at low household electrification rates, but negative effects at high household electrification rates[4]. Importantly, these results suggest that benefits of thermal power may 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)). Given the longevity of power plants, policymakers must anticipate these changes in household preferences when determining the energy mix in developing countries[5].

[2]Because these plants required multi-year of planning and had lifespans ranging from 30 to 50 years, locational decisions tend to be made independently of contemporaneous economic activity.

[3]We proxy access to electricity with the percentage of households in a county with electric lighting in 1940, and levels of pollution with coal consumption per square mile in 1927 based on coal consumption for the state in which the county is situated. For example, the $H_PHHL1940$ x $H_CCSM1927$ bin is high percentage of households with lighting in 1940 and counties with high coal consumption per square mile in 1927.

[4]Our results also indicate that the impact of new thermal power plants vary according to the level of pollution in the baseline: for low levels of pollution, the net benefits tend to be smaller.

[5]According to the World Bank, over 1.2 billion people - 20 percent of the world's population - are still

Overall, the changes in power generation from 1940 to 1960 implied a welfare loss of about $3.7 billion (in 2001 dollars). Adjusting for the proportion of U.S. population included in our study (0.50 versus their 0.80), the share of coal consumption by electric utilities in our baseline (0.15 versus their 0.65), and the length of the period of our analysis (two decades versus their one decade), our estimate of the willingness to pay to avoid pollution arising from the burning of coal in the power sector is a bit more than a fourth of the one found by Chay and Greenstone (2005): $12.8 billion versus $45 billion (in 2001 dollars). Keeping only the net costs of electrification in the calculation, which might reflect costs of air pollution only, our estimate jumps to $16.4 billion. Therefore, even excluding the amenity value of electricity, the valuation of air quality seems to be lower in the U.S. in the middle of the twentieth century.

This paper proceeds as follows: Section 2 discusses the history of thermal generation in the United States. Section 4 describes the data. Section 5 presents the empirical framework. Section 6 presents the results. Finally, Section 7 concludes.

2 Historical Background

During the mid-twentieth century the U.S. witnessed a sharp rise in thermal power generation. Between 1930 and 1960, over 1,000 new power plants were built, over 80 percent of which were powered by coal. During this period, over 100,000 MW of steam capacity were added, compared to less than 24,000 MW of hydro capacity (see figure 2).

In part, this expansion was driven by increased demand for electricity. Industrial electricity consumption rose sharply during World War II and remained high during the post-war period. Growth in residential electricity consumption was another important contributor to the expansion, and outpaced industrial growth for most of this period. The extension of electrical services into the rural parts of the country created a new pool of residential customers,

without access to electricity worldwide, almost all of whom live in developing countries.

and decreases in prices led to the widespread diffusion of major household appliances[6].

The expansion in thermal power generation was also a result of technological advances in the power industry. Improvements in boiler technology increased thermal efficiency. The development of high voltage transmission lines also allowed power companies to exploit economies of scale, building large generation plants outside of cities[7].

The availability of a source of local thermal generation offered a number of benefits to nearby communities. Proximity to a source of generation increased the likelihood of residential electricity access. Recent evidence suggests a high willingness-to-pay for this amenity (see Lewis and Severnini, 2014). Household electrification dramatically reduced the time intensity of home production. One study found that access to pumped water saved the average family almost one hour per day in the collection of water (REA, 1938). Meanwhile, without electricity a single load of laundry could take nine hours to wash and iron (Greenwood, Seshadri, and Yorukoglu, 2005). Although somewhat speculative, some estimates suggest that a family of four would have save twenty hours per week on housework (Greenwood and Seshadri, 2005).

On the other hand, these fossil-fuel power plants led to increased local levels of air pollution. Atmospheric air pollution dispersion is a function of the pollutant density, meteorological conditions, local terrain, and smoke stack height. Recent evidence from Illinois shows that 40 percent of primary $PM_{2.5}$ exposure occurs within 30 miles of a power plant, with another 30 percent occurring between 30 and 125 miles[8] (Levy et al. 2002). Thermal power generation was an important contributor to air pollution. As thermal electricity production expanded, these plants accounted for an increasing fraction of total domestic coal consumption, rising from just 10 percent in the 1920s to almost 50 percent by 1960, as shown in figure 4.

[6]These price declines were reinforced by federal programs, such as FHA, which offered lower interest loans to purchase major domestic appliances.

[7]The average capacity of steam plants rose from 35 MW for plants built in the 1920s and 1930s to over 190 MW for plants built in the 1950s.

[8]In contrast, secondary sulfates and nitrates disperse more widely, with over 50 percent of exposure occurring beyond 125 miles.

Air pollution was a significant issue in cities throughout the United States in the first half of the twentieth century. Although monitoring networks would be built decades in the future, photographic evidence, newspaper articles, city-level legislation, city studies measuring smoke or dustfall, and in a few instances city-level measures of TSP attest to the severity of the issue.

Pollution was frequently mentioned in newspapers and was often important enough to warrant a front-page mention. On December 1915, the Day Book (Chicago) carried a full page article "$500,000 Goes Up In Smoke Probe as the Railroads Dodge Electrification." A search of Chronicling America, the Library of Congress database of digitized newspapers covering 5.2 million pages spanning 1836 to 1922, yielded 40,000 pages that mentioned pollution. 5,400 of these mentions were on the front page. Smoke Nuisance appeared on 3,995 pages and 293 front pages.

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 (Goklany, 1999, p. 15). The remaining five used relatively little coal and so were not significantly affected. Dozens of smaller cities also passed legislation. While the passage of municipal legislation suggests that the problem was substantial and widespread, Stern (1982) states that in roughly three-quarters of the city ordinances, there was no provision for a new or existing agency to enforce the regulation. Table 1 lists cities that passed smoke abatement legislation and had smoke abatement agencies prior to 1930.

In 1930 the U.S. Public Health Service received an appropriation of $25,000 from Congress to study air pollution in cities (Ives et al., 1936). As the introduction to the study noted, "*In recent years the pollution of the atmosphere by smoke and other impurities, especially in the larger cities, has been the subject of much discussion. (. . .) There has been much discussion as to the injurious effects of smoke upon health.*" (Ives et al., 1936, p. 1). Given their limited resources, the goal of the 1930 study was solely to collect data on air quality in large American cities. Owens automatic air filters were run continuously in fourteen large

U. S. cities beginning in July 1931. Total suspended particulates (TSP) were also sampled, although with lower frequency, because of the higher cost of data analysis.

Air quality in U.S. cities in the early to mid-twentieth century was similar to air quality in some developing countries today. Table 2 presents selected estimates of particulate pollution in the U.S. and developing countries. Particulate pollution in the U.S. was high in the 1910s and 1930s[9]. Evidence on levels of dustfall from New York and Pittsburgh suggest that levels were increasing over the period 1915-1925 and remained high into the mid-1940s (Davidson and Davis, 2005; Eisenbud, 1978). Pollution in Chinese cities in the 1980s and early 1990s was similar to winter air pollution in large U.S. cities in the 1930s.

Pollution only began to drop after World War II as households began to switch to using natural gas and oil, instead of coal for home heating. By then, electricity generation had moved out of city centers and into suburban and nearby rural areas. Further, smokestacks were taller and so could disperse pollution over larger areas.

3 Conceptual Framework

In order to examine the welfare consequences of an expansion in thermal power generation, we develop a simple partial equilibrium model.

3.1 Set-up

We assume that a representative consumer has Cobb-Douglas utility function over electricity (E), health (H), and a composite good that we call shelter (S). We also assume that health is a function of air quality (A), and that there is a market for power and shelther, but not for air quality. Finally, we assume that air quality is directly affected by thermal power

[9]Evidence from Pittsburgh and Cleveland suggest that TSP levels in these cities in the 1910s may have been worse than in Chicago (Davidson, 1979, p. 1036). Chicago had a very favorable geographic location on a flat plain with constant breezes. It also burned an extremely high volume of coal per square mile. See Goss (1915).

generation. Therefore, the consumer's problem is

$$\begin{aligned} \text{Max}_{E,S\in\mathbb{R}^2_+} U(E,H,S) &= E^{\alpha}H^{\beta}S^{\gamma} \\ \text{s.t. } dE+rS &= Y \\ H &= h_0+h_1A \\ A &= a_0-a_1E, \end{aligned} \tag{1}$$

where d and r represent prices of electricity and shelter, respectively, Y income, h_0 consumer's health endowment, h_1 the marginal effect of a pollution-mortality dose-response function, a_0 initial level of air quality faced by consumer, and a_1 the effect on air quality coming from the marginal unit of thermal power generated. We assume that all these parameters, including α, β, and γ, are positive. We define E as the share of hours of the day that the representative consumer uses electricity to facilitate graphical interpretation of the results later on. An expansion of thermal power generation allows the consumer to increase her use of electricity during the day.

The consumer's problem can be simplified to

$$\begin{aligned} \text{Max}_{E,S\in\mathbb{R}^2_+} U(E,S) &= E^{\alpha}(\theta-\delta E)^{\beta}S^{\gamma} \\ \text{s.t. } dE+rS &= Y, \end{aligned} \tag{2}$$

where $\theta = h_0+h_1a_0$ and $\delta = h_1a_1$, and transformed to

$$\text{Max}_{E\in\mathbb{R}_+} \ln U(E) = \alpha \ln E+\beta\ln(\theta-\delta E)+\gamma\ln\left(\frac{Y-dE}{r}\right). \tag{3}$$

The solution to this problem can be expressed by

$$f(E)\equiv[(\alpha\delta+\beta+\gamma\delta)d]E^2-[(\alpha\delta+\beta)Y+(\alpha+\gamma)\theta d]E+\alpha\theta Y=0. \tag{4}$$

As long as $\alpha < \frac{\beta}{(\theta-\delta)} < \alpha+\gamma$, which we assume for simplicity to treat E as a share, $f(1) < 0$. Given that $f(0) > 0$, $f(1) < 0$, and $f(E)$ is minimized at a positive value of E, there is at least one root of the quadratic equation (4) between zero and one. Therefore, at the optimal,

$$E^* \;=\; E(d, r, Y, \alpha, \beta, \gamma, h_0, h_1, a_0, a_1) \;\in\; (0, 1). \tag{5}$$

Now, at the optimal, $S^* = S(d, r, Y, \alpha, \beta, \gamma, h_0, h_1, a_0, a_1)$ as well, so we can express shelter/housing prices r as

$$r = S^{-1}(d, S^*, Y, \alpha, \beta, \gamma, h_0, h_1, a_0, a_1), \tag{6}$$

a function of conditions in the electricity markets (d), the state of the economy (S^*, Y), consumer's preferences (α, β, γ), consumer's health condition (h_0, h_1), and air quality faced by the representative consumer (a_0, a_1). In our empirical framework, we focus on the reduced form health function $H = \theta - \delta E$, and equation (6).

3.2 Welfare Consequences

To understand the welfare consequences of an expansion in thermal power generation, we proceed with our partial equilibrium approach. First, we offer a microfoundation for figure 1 using the utility function expressed (2) for a given S. Basically, we plot

$$U(E) = E^{\alpha}(\theta - \delta E)^{\beta} \tag{7}$$

in figure 4 using $\alpha = \beta = \theta = \delta = 1$[10], and show that it mirrors figure 1. Recall that $\theta = h_0 + h_1 a_0$ and $\delta = h_1 a_1$. Second, we examine how the shape of the utility function (7) changes with different levels of pollution. We focus on changes in parameters a_0, a_1 and h_1 associated with high, medium, and low levels of pollution.

[10] In figure A.1, in the appendix, we show how the graph of the utility function in figure 4 changes when $\alpha < \beta$ (electricity is less valuable than air quality) and $\alpha > \beta$ (electricity is more valuable than air quality).

Changes in a_0. Holding all other parameters constant, for high levels of pollution in the baseline (small a_0), the graph of the utility function tilts downward, as depicted in figure 5. Notice that this is a result of changes in θ. It takes just a low level of electricity consumption to make the costs of thermal power generation exceed the benefits of steam electricity. However, for low levels of pollution in the baseline (large a_0), the utility function tilts upward. The benefits of steam electricity offset the costs of pollution associated with thermal power generation in a large range of electricity consumption. In this case, the marginal utility for high levels of pollution in low electricity consumption scenarios is positive but smaller than for low levels of pollution. We can see this in the cut provided by the first vertical solid line from the left. In high power consumption scenarios, such as the one indicated by the third vertical solid line from the left, the marginal utilities are negative, and larger in absolute terms for high levels of pollution.

Changes in a_1. Holding all other parameters constant, when pollution created by thermal power generation affects air quality just a little (small a_0), which might happen in places with high levels of pollution, the graph of the utility function tilts upward, as depicted in figure 6. In this case, only δ changes. Thermal power generation has to reach really high levels until the pollution costs associate with it dominate the benefits of steam electricity. On the other hand, when that marginal effect is high (large a_1), which might be the case in places with low levels of pollution, the utility function tilts downward. The benefits of steam electricity are offset by the costs of pollution associated with thermal power generation almost right away. Observe that the order of magnitude of the marginal utilities in low and high power consumption scenarios is inverted relative to changes in a_0.

Changes in h_1. Holding all other parameters constant, when the marginal effect of a pollution-mortality dose-response function is low (small h_1), which might be true in places with high levels of pollution, the graph of the utility function tilts downward, as depicted in figure 7. Notice that both θ and δ change in this case. Because a_0 is usually larger than a_1, the change in θ should be larger than the change in δ in absolute terms. Nevertheless,

when that marginal effect is high (large h_1), which might happen in places with low levels of pollution, the utility function tilts upward. In this situation, the behavior of marginal utilities is similar than in the case of changes in a_0.

Our empirical results will be shown to be consistent with changes in a_1. For a scenario with low consumption of electricity, the marginal utility is positive and higher for high levels of pollution. For a scenario with high consumption of electricity, the marginal utility is negative and higher for low levels of pollution in absolute terms.

3.3 Transmission Lines and Renewable Energy

It is interesting to mention what happens when a location has been granted access to steam electricity through the power grid but is upwind from the thermal power plant, or when electricity is generated locally by renewable sources such as solar or wind. One should expect the benefits of electricity to not be offset by costs of pollution when power consumption increases. Indeed, in those cases, air quality is not affected by electricity generation, implying that $a_1 = \delta = 0$. Figure 8 shows that the utility function increases monotonically in those scenarios, and therefore access to electricity is always welfare improving.

4 Data Description

To address the benefits and costs of the expansion of thermal power generation, we combine newly digitized plant-level data on electricity production from Federal Power Commission reports, with historical county-level data from 1940 to 1960 drawn from Censuses of Population and Housing (Haines and ICPSR, 2010; DOC and ICPSR, 2012) and Vital Statistics of the United States (Fishback, Haines and Kantor, 2007; Fishback et al., 2011; and Fishback et al., s.d.). Our main outcomes of interest are (decadal) median dwelling value, (decadal) median dwelling rent, and (annual) infant mortality rates. Our key explanatory variables are a (decadal) measure of access to electricity, and (annual) coal consumption by steam power

plants. Our empirical analysis is carried out using a balanced panel of 824 counties in U.S., which are depicted in figure 9. Our sample includes about half of the U.S. population.

The measure of thermal electricity access is constructed as the county-centroid distance to the nearest steam power plant with at least 50 MW of nameplate capacity, as in Lewis (2014a). Smaller plants are excluded from the analysis to limit concerns over endogenous site location. To construct this measure, we rely on a set of seven maps produced by the Federal Power Commission in 1962 (U.S. Federal Power Comission, 1963). These maps identify the location of all power plants in the U.S., along with various plant characteristics. Figure 10 presents a subsection of one of these maps, where each circle and square corresponds to a particular plant. Using GIS software, we digitize this information, and combine it with historical information on the timing of plant openings to construct a panel of plants for the period 1930 to 1960. As the power grid expands in the U.S. during the mid-twentieth century, more plants are built, and, consequently, distances reduce considerably. Figure 11 shows the distribution of power plants across the country by size and decade. As we can see, there is a remarkable increase in the number of plants over time.

It is important to stress that distance to power plants is a strong predictor of household electricity access by mid-twentieth century U.S. Indeed, limitation in transmission technology created an incentive to supply electricity locally (see Lewis, 2014a). As a result, our measure of thermal electricity access should influence local housing prices through improvements in household amenities (Lewis and Severnini, 2014). Distance to plants should also capture the disamenity associated with exposure to plant emissions. In fact, air pollution associated with thermal generation has been shown to be concentrated locally (Levy et al., 2002)[11].

The measure of coal consumption by steam power plants is created from extremely detailed information at the plant-level coming from the Federal Power Commission's Steam-Electric Plant Construction Cost And Annual Production Expenses series (U.S. Federal Power Comission, 1947-62). Among many other variables, those volumes include nameplate

[11]Recent evidence from Illinois suggests that over 2/3 of $PM_{2.5}$ exposure occurs within 125 miles of a power plant (Levy et al., 2002).

capacity, fuel consumption, and net electricity generation for all thermal power plants in the U. S. from 1938 onwards. The data begin in 1938, because it is the first year covered by that series. In this current version of the paper, we are using data of coal consumption and infant mortality until 1949, but we plan to extend that analysis until 1962, which represents the launch of the modern American environmental movement with the Rachel Carson's influential Silent Spring[12].

We divide the data into nine bins based on the percentage of households in a county with electric lighting in the 1940 Census of Housing and on bituminous coal consumption per square mile in 1927 (Tryon and Rogers, 1927), the closest year for which detailed state statistics are available. We use lighting, because it is the first thing households obtain when they gain access to electricity. Besides lighting, one could measure access to electricity in the baseline by looking at the percentage of the households in a county with refrigerator or electric stove. We use bituminous coal consumption per square mile, because it is as a proxy for baseline pollution[13]. As we discuss further in the identification section, counties were divided into these nine bins, because we expected counties with different levels of coal consumption and access to electricity to respond differently to being located closer to major power plants.

Table 3 shows the number of counties in each bin, the average percentage of households in the county with electric lighting, and the average coal consumption per square mile in 1927 for the state in which the county is situated. H, M, and L are counties with High, Medium, or Low lighting or coal consumption. For example, the $H_PHHL1940$ x $H_CCSM1927$ bin is high percentage of households with lighting in 1940 and counties with high coal consumption per square mile in 1927. Across all counties, 65 percent of households had electric lighting and 355 tons of coal were burned per square mile per year. The variation across the bins is large. For example, in counties with high lighting and coal, 88 percent of households

[12]Digitization of infant mortality data for the 1950s is still in progress.

[13]Alternative specifications using coal consumption per capita give very similar results. Anthracite coal is much less polluting than bituminous coal.

had lighting and 772 tons of bituminous coal were burned per square mile. In contrast, in counties with medium lighting and coal, 59 percent of households had lighting and 98 tons of bituminous coal were burned per square mile. In counties with low lighting and coal, 27 percent of households had lighting and 16 tons of bituminous coal were burned per square mile. More generally, otherwise similar counties in terms of households with lighting burned very different amounts of coal.

Table 4 shows summary statistics for counties in these nine bins in 1940, the change from 1940-1960, and the percentage change from 1940-1960. In panel A, it is worth noting that about one-third of counties and 62.5 percent of the population are concentrated in counties with high access to lighting and high coal consumption. In terms of distance to a power plant of at least 50 MW, these counties are 29 miles from any type of plant, 30 miles from a steam plant and 138 from a hydroelectric plant. Overall 66.6 percent of the population is in high coal consumption states and 81.5 percent are in high access to lighting areas. In terms of distance to a power plant of at least 50 MW, the average county is 51 miles from any type of plant, 56 miles from a steam plant and 142 from a hydroelectric plant.

Panel B shows the changes in summary statistics from 1940 to 1960, and Panel C represents these changes in percentages. On average across counties, population increased by 44 percent, the number of dwellings increased 63 percent, and housing values and rents increased by 105 and 116 percent. The post-war prosperity is reflected in the lower number of individuals per dwelling and the large increase in housing values and rents. By 1960, the average county is considerably closer to a power plant than they were in 1940, and the changes are much larger for steam electric plants. The distance fell 18 percent for hydro plants, while they fell 52 percent for steam plants. For the vast majority of counties, the closest plant was a steam electric plant.

Additional data is used as controls in our analysis. "Geography" variables include time-varying controls for 10-year moving averages for precipitation and temperature, degree days below 10C, and degree days above 29C, and latitude and longitude. "Economy" variables

include total employment, manufacturing employment, and manufacturing payroll per worker at the baseline (1940). Summary statistics for these variables are reported in tables A.1 and A.2.

5 Empirical Framework

The main objective of the empirical analysis is to identify the impact of thermal power generation on health outcomes and housing prices. Although the benefits of electricity access might be readily apparent, it is unclear whether families are aware of the health hazards posed by these plants. Some particles such as soot or smoke are large enough to be seen, but many pollutants are colorless, odourless, and are not well monitored until the 1970s. To examine the saliency of these costs, we start by studying the impact of thermal plant emissions on infant mortality. We estimate the following model:

$$MortRate_{ct} = \alpha + \beta Pollution_{ct} + \theta X_{ct} + \lambda_t Z_c + \eta_c + \phi_{st} + \varepsilon_{ct}, \quad (8)$$

where $MortRate$ represents infant mortality rates (per 1,000 live births), our proxy for health outcomes, and c stands for county, t for time, and s for state. X represents time-varying covariates such as temperature, precipitation, and distance to the nearest hydro dam, Z time-invariant controls (e.g., latitude, longitude, and initial distribution of economic activity), η a set of fixed effects for counties, ϕ a set of fixed effects for state-year, and ε an idiosyncratic term.

We rely on four alternative measures of exposure to thermal plant emissions ($Pollution_{ct}$) to estimate equation (8): total power plant coal consumption within 50 miles, net steam generation within 50 miles, steam capacity within 50 miles, and the interaction of plant hours connected and local steam capacity[14]. In this specification, we expect β to be negative, as

[14]This distance is chosen to correspond to the range in which the majority of particulates would be dispersed. According to Levy et al. (2002), approximately 40 percent of primary $PM_{2.5}$ total exposure is located within 30 miles of the power plants. Another 30 percent occurs between 30 and 125 miles, with the

all four measures are directly related to air pollution, which is in turn harmful for health (Stieb et al., 2012; Currie et al., 2013). This equation is estimated using annual data for the period 1938 to 1949, although the period of analysis will eventually be extended to span the period 1938 to 1962.

Our identifying assumption is that annual changes in plant emissions are unrelated to contemporaneous determinants of infant health. This assumption should be satisfied for local steam capacity, given that additions to plant capacity required multi-year planning and were made on the basis of an extended time-horizon. In contrast, annual coal consumption and thermal generation may have been influenced by contemporaneous economic activity. 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 address this challenge, we consider alternative specification, in which we control directly for measures of local economic conditions.

After examining the pollution-mortality relationship, we turn to the impact of expansions in thermal power generation on housing prices. Our goal is to capture the extent to which households are willing to tradeoff the benefits of local electricity access with the costs of increased pollution. Because an explicit market for clean air does not exist, we employ the hedonic price method to estimate the economic value of this non-market amenity to individuals. Hedonic theory predicts that an economic bad, such as air pollution, will be negatively correlated with housing prices, with all other characteristics held constant. Meanwhile, given that access to electricity may be perceived as an amenity by households (Lewis and Severnini, 2014), housing prices might be affected positively by electrification. Therefore, the hedonic method allows us to obtain the net effect of electricity on property values. Our estimating equation here is

$$HPrice_{ct} = \alpha + \beta DistPP50Steam_{ct} + \theta X_{ct} + \lambda_t Z_c + \eta_c + \phi_{st} + \varepsilon_{ct}, \quad (9)$$

remainder beyond 125 miles.

where $HPrice$ represents either median dwelling value (owner-occupied) or median dwelling rent (renter-occupied), $DistPP50Steam$ represents (*the negative of*) the distance to the nearest steam power plant with at least 50 megawatts of nameplate capacity[15], and c stands for county, t for time, and s for state. Again, X represents time-varying covariates such as temperature, precipitation, and distance to the nearest hydro dam, Z time-invariant controls (e.g., latitude, longitude, and initial distribution of economic activity), η a set of fixed effects for counties, ϕ a set of fixed effects for state-year, and ε an idiosyncratic term. In this specification, if β is positive, it represents the net benefits of having access to electricity, indicating that individuals value more the ability to use electricity in their properties than the air pollution resulting from thermal power generation. If β is negative, then the costs of pollution exceed the benefits of electrification.

In order to understand how the costs of air pollution arising from power generation contrast with the amenity value of electricity, we modify equation (9) to include interactions between distance to steam power plants with baseline levels of air pollution - proxied by coal consumption per square mile based on state-level total consumption in 1927 -, and baseline levels of access to electricity - measured by the percentage of households with lighting in a county in 1940. The idea is that smog coming from coal burning represents a very salient cost of pollution faced by individuals, and that power usage at home reflects the value of electricity as an amenity. The estimating equation becomes:

$$\begin{aligned} HPrice_{ct} &= \alpha + \theta X_{ct} + \lambda_t Z_c + \eta_c + \phi_{st} \\ &\quad + \gamma_{LH}(DistPP50Steam_{ct} * L_PHHL1940_c * H_CCSM1927_c) \\ &\quad + \gamma_{LM}(DistPP50Steam_{ct} * L_PHHL1940_c * M_CCSM1927_c) \\ &\quad + \gamma_{LL}(DistPP50Steam_{ct} * L_PHHL1940_c * L_CCSM1927_c) \end{aligned} \tag{10}$$

[15]Again, we use distance to power plants because they (i) convey how easy it is to get access to electricity when the power grid is still expanding, and (ii) reflect undesirable negative externalities such as air pollution, as shown by Davis (2011). Davis (2011) examines responses of housing prices to openings of fossil fuel power plants in the U.S. in the 1990s, and finds that neighborhoods within two miles of plants experience 3-7 percent decreases in housing values and rents.

$$+\gamma_{MH}(DistPP50Steam_{ct} * M_PHHL1940_c * H_CCSM1927_c)$$
$$+\gamma_{MM}(DistPP50Steam_{ct} * M_PHHL1940_c * M_CCSM1927_c)$$
$$+\gamma_{ML}(DistPP50Steam_{ct} * M_PHHL1940_c * L_CCSM1927_c)$$

$$+\gamma_{HH}(DistPP50Steam_{ct} * H_PHHL1940_c * H_CCSM1927_c)$$
$$+\gamma_{HM}(DistPP50Steam_{ct} * H_PHHL1940_c * M_CCSM1927_c)$$
$$+\gamma_{HL}(DistPP50Steam_{ct} * H_PHHL1940_c * L_CCSM1927_c)$$
$$+\varepsilon_{ct}.$$

Recall that $DistPP50Steam$ represents (*the negative of*) the distance to the nearest steam power plant with at least 50 megawatts of capacity. $PHHL1940$ stands for Percentage of Households with Lighting at the baseline (1940), and $CCSM1927$ for Coal Consumption Per Square Mile at the baseline (1927). H, M, L stand for High, Medium, and Low, respectively, and represent bins for the top, middle, and bottom tercile of the distribution of those variables. In constructing these bins, the 33th percentile of $PHHL1940$ was 45.6 percent, and the 66th percentile was 72.9 percent. Just for the sake of comparison, the average of $PHHL1940$ in our sample is 65.3 percent. Similar numbers for $CCSM1927$ are 42.84, 159.56, and 355.03 net tons of bituminous coal consumed per square mile.

The interpretation of γ's should be made easier with the help of figure 1. Net benefits of steam electricity might increase as more households get access to electricity, but may reach a point after which the trend is reverted. In fact, for low rates of electrification, the amenity value of electricity may exceed the costs associated with air pollution arising from power generation. Assuming that housing markets capitalize that amenity into rental rates and home values, we should expect positive marginal net benefits $\gamma_{.L}$'s. For high levels of access to electricity, however, individuals may put more value on environmental amenities such

as air quality. Indeed, once electrified, a household might find undesirable having a steam power plant built ten miles closer to its property because that might mean higher levels of air pollution. In that case, rental rates and home values depreciate, and the marginal net benefits $\gamma_{.H}$'s become negative. Lastly, for medium levels of access of electricity, counties may be around the turning point, so the sign of $\gamma_{.M}$'s may be ambiguous.

Equation 10 also addresses the heterogeneity of the impact of electrification across initial levels of pollution. For the same rate of access to electricity, let us say low, households may value electricity more in places with higher air pollution at the baseline. In plain English, in counties where households already face poor air quality, they better get the benefits of electricity, which may add just a little more pollution. Another explanation may be sorting based on preferences for air quality: individuals living in more polluted locations may be less concerned about the adverse effects of pollution, or more willing to engage in avoidance/defensive behavior.

Before presenting the results, a final caveat should be emphasized. Even if the identifying assumptions are satisfied, and power plant emissions are exogenous to local economic conditions, the estimates of β from equations (9) and (8) and γ's from equation (10) may still not capture the direct impact of thermal power plant pollution on health outcomes and residential home values. Suppose, for example, that increases in thermal generation lead to an expansion in local industrial production, which in turn contributes to local air pollution. Our estimates capture the reduced form impact of thermal plant generation on mortality (and housing prices), but we cannot distinguish whether the effects are driven by plant emissions or industrial pollution[16]. The distinction between plant emissions and industrial emissions has relevance for policy: if local air pollution is primarily affected by an expansion in industrial production, changes in energy mix will do little to mediate the negative health effects of thermal generation. In future work, we hope to exploit differences in baseline industry composition to shed light on this question.

[16]This issue is particularly salient during the early sample period, when electric utilities accounted for just 15 percent of total domestic coal consumption.

Finally, we expect the coefficients in equation (10) to be more statistically and economically significant when we use rental rates instead of home values as the dependent variable. Indeed, renters are more mobile than homeowners, so they may be more sensitive to access to electricity and pollution. Also, home values reflect the present value of stream of rental rates for all the years that a house is supposed to last. Assuming that the benefits of electrification are permanent, and the costs of pollution are temporary, home values should vary less than rental rates. Those assumptions might be very plausible because once electrified, one expects to have access to electricity continuously afterwards. But the costs of power access in terms of air pollution might change over time depending on the emergence of environmental regulations, probably coming into place once a location reaches higher levels of electrification, when the marginal value of acess to electricity attenuates.

6 Results

We now present our estimates of the impact of thermal power generation on health outcomes and housing prices in mid-twentieth century U.S. We start by reporting the effects of pollution arising from steam electricity production on infant mortality in that period. Next, we discuss the average net benefits of steam electricity on home values and rents, which take into account the amenity value of electricity and the costs of pollution associated with it. Then, we introduce our main results, which reveal when the amenity value of thermal power may be more important than the pollution costs, and when those costs may dominate. Back-of-the-envelop calculations are provided to give a sense of the magnitude of those effects. Robustness checks are also presented to show that our results are not sensitive to the definition of key explanatory variables.

6.1 Infant Mortality Results

Table 5 reports the estimates of β from equation (8). The first row reports the results using coal consumption (100,000s of tons) within 50 miles as a measure of local plant emissions. The estimates are all positive and statistically significant. Interestingly, the inclusion of economic covariates - in column 4 - increases the magnitude of the point estimates, suggesting improved local economic conditions may have partially offset the negative health effects of increased emissions, and that failing account for these covariates would lead to downward biased estimates.

The period 1938 to 1949 witnesses a 37 percent decline in infant mortality. In the absence of the expansion in thermal coal consumption, however, these health improvements would have been even greater. Applying our preferred estimates (column 5), we calculate that infant mortality rates would have been 41 percent had thermal generating capacity remained at its 1938 level.

Rows 2-4 report the results based on alternative measures of exposure to power plant emissions. Increases in contemporaneous local thermal generation are associated with higher infant mortality rates. The point estimates for net thermal generation (in 100 million of kilowatt hours) are all positive and statistically significant. Mortality rates are also associated with the number of hours that these plants were online: the coefficients of the interaction term are all positive and significant. There is some evidence that installed thermal capacity had negative effects on health, although the point estimates are not statistically significant. Given the limited time horizon and the lack of annual variation in installed capacity, these estimates lack precision.

Together, the results in table 5 suggest 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). These findings highlight the direct health costs associated with local access to thermal power. The extent to which individuals were aware of these health risks remains unclear. The enactment of municipal

smoke abatement legislation in many cities even before 1930 (see table 1) and extensive media coverage of pollution suggest that the public may have been cognisant of these issues, despite the absence of local air quality measures. How families traded off these costs against the benefits of electricity access will be explored in the subsequent section.

6.2 Average Net Effects of Access to Steam Electricity

The estimates of the marginal net benefits of access to thermal power are shown in table 4. The outcome variable is log of rental rates in the top panel of the table, and log of home values in the bottom panel. The independent variable of interest is $DistPP50Steam$, which is (*the negative of*) the distance to the nearest steam power plant with at least 50 megawatts of nameplate capacity, and represents availability of nearby electricity. The specification in the first column controls only for county and year fixed effects, and the results seem positive and statistically significant. Taking at face value, rental rates and home values increases 1.26 and 1.54 percent, respectively, when a new steam power plant is built ten miles closer to a household's residence.

The specification in the second column takes also into account potential linear trends in the dependent variables that might be particular to each state. As a consequence, the net benefits drop drastically, and are no longer statistically distinguishable from zero. The third-column specification includes geographical features of each county, and the estimates decrease even more. The fourth-column specification incorporates the state of the local economy at the baseline, and again we observe reductions in the coefficients. Finally, the fifth-column specification, our preferred one, replaces the state linear trends with state-year fixed effects while keeping all previous covariates unchanged. The point estimates drop once more, becoming virtually zero.

When discussing the estimates of the housing price-air pollution gradient in the literature, Chay and Greenstone (2005) point out that they are severely biased towards zero because of the omission of relevant variables in the analyses. They argue that the "conventional" cross-

sectional and fixed-effects approaches to estimate the marginal willingness to pay (MWTP) to avoid air pollution may be very sensitive to specification, and occasionally produce the perverse sign, indicating that pollution and housing prices are positively correlated. Although our average estimates of the housing price-electricity gradient are slightly positive, and steam power generation is associated with a variety of air pollutants, our results should not be seen as having the pervese sign. As we have mentioned before, in our context, the costs of undesirable air pollution may be offset by the value of electricity in improving the living conditions of a household. Indeed, Lewis (2014a, 2014b) points to important changes in home production with the diffusion of electricity into the home in the U.S. from the 1930s to the 1960s, and Lewis and Severnini (2014) provide evidence that the amenity value of electricity for the same time period is economically sizeable.

6.3 Benefits and Costs of Access to Steam Electricity

Given that our estimates of the average impact of thermal power on housing prices are virtually zero, and this might reflect pollution costs being offset by the amenity value of accessing steam-generated electricity, we now turn to our main results, which exploit heterogeneity across subpopulations. If there is heterogeneity across households in tastes for clean air, then households may self-select into locations on the basis of those unobserved differences. In this case, estimates of MWTP may reflect the preferences of subpopulations that, for example, place a relatively low valuation on air quality. Likewise, if households value electricity differently, they may sort into areas with better or worse power access according to their preferences.

As explained in our methodology section, we split U.S. counties into nine bins of air pollution-access to electricity combinations at the baseline. We proxy air pollution with coal consumption per square mile in 1927 ($CCSM1927$), and access to electricity with the percentage of households in a county with lighting in 1940 ($PHHL1940$), the first decade of our analysis. Our bins represent combinations of each tercile of the distribution of those

variables. Then, we use the rollout of the U.S. power grid by mid-twentieth century to estimate the marginal net benefits of electrification in each bin. To be more precise, we estimate the marginal net benefits of having a steam power plant built ten miles closer to a household's residence - the marginal effect of $DistPP50Steam$ - for each bin.

We present our main results in table 7. The five columns in that table report estimates from the same specifications mentioned in the previously for the average effects. We discuss only the coefficients of our preferred specification: the fifth column. Let us start with the marginal net benefits of electrification for renters in panel A. As depicted in figure 1, the marginal net benefit of electrification is expected to be positive in counties with low rates of access to electricity in the baseline ($L_PHHL1940$). Indeed, they are 5.05, 1.81, and 0.2 percent for high ($H_CCSM1927$), medium ($M_CCSM1927$), and low ($L_CCSM1927$) levels of pollution in the baseline, respectively, although the last estimate is not statistically significant. That is, having a steam power plant built ten miles closer to a household's residence increases rental rates by aproximately 5.05, 1.81, and 0.2 percent, depending on pollution concentration in the baseline. This heterogeneity in the magnitude of the coefficients might reflect variation in preferences for air quality. Households living in places with high coal consumption to start with might be more tolerant with air pollution than those living in places with low pollution levels in the baseline. Another explanation has to do with levels. Since coal consumption of power plants in 1940 is around 15 percent, as shown in figure 4, the additional pollution arising from power generation might not be salient. Thus, households may focus all attention on the benefits of electricity at home or at the workplace.

Figure 1 also leads us to expect negative marginal net benefits of electrification for high rates of access to electricity in the baseline ($H_PHHL1940$). That is exactly what we find: when a steam power plant is installed ten miles closer to a household's residence, rental rates drop by 0.9, 1.6 and 3.07 percent for counties classified as $H_CCSM1927$, $M_CCSM1927$, and $L_CCSM1927$, respectively[17]. Again, the heterogeneity in the magnitudes of those

[17]As mentioned before, Davis (2011) examines housing values and rents for neighborhoods in the U.S. where fossil fuel power plants were opened during the 1990s. Compared to neighborhoods with similar

coefficients might reflect sorting or sensitivity of the overall local pollution to the additional pollution arising from power generation. Lastly, for counties with medium rates of access to electricity, the sign of the marginal net benefit of electrification is ambiguous. In terms of figure 1, those counties are located around the turning point, where the effect could be positive or negative depending on the side that the county lies in the graph. Panel B, which shows our findings for home values, paints a similar picture. The point estimates are a bit smaller than those from the analysis with rental rates, but the main patterns are preserved. The statistical power is also slightly reduced, but that was expected because renters usually respond more promptly to changes in attributes of their place of residence than homeowners.

6.4 Interpretation and Welfare Calculations

To get a sense of the magnitude of those effects, let us turn to table 8. In order to facilitate the understanding of our back-of-the-envelop calculations, we reproduce some information from the summary statistics table in the first five columns, and the coefficients of our preferred specification in column 6. In the seventh column, we present the marginal net benefits of electrification at the mean change of distance to steam power plants from 1940 to 1960 for each bin. As we can see, in those two decades of our analysis, housing prices may have increased by up to 15 percent because of access to electricity in counties with low levels of lighting in the baseline. On the other hand, rental rates and homes values may have decreased by up to 9.2 percent due to the additional pollution arising from power generation in counties with high levels of access to electricity in the baseline.

As discussed previously, the population is distributed unevenly across the nine bins combining access to electricity and pollution levels in the baseline. In column 8, we weight the effects by the number of households in each bin. In the calculations, we use the average percentage of homeowners for the years 1940, 1950 and 1960 - 53.5 percent - because it is

housing and demographic characteristics, neighborhoods within two miles of plants experienced 3-7 percent decreases in housing values and rents. Adjusting for the distance to power plants considered in his study, our estimates would be much lower: 0.18, 0.32, and 0.61 percent for counties classified as $H_CCSM1927$, $M_CCSM1927$, and $L_CCSM1927$, respectively.

unusually low in 1940. For rental rates, we compute the implied effect on home values assuming that a dwelling lasts for 100 years, which is roughly the 95 percentile of the distribution of life expectancy of houses in the 2013 American Housing Survey[18]. For home values, we just use prices and quantity of dwellings in the baseline. In column 9, we sum only the effects computed using statistically significant coefficients from column 6. Apart from the difference in the proportion of renters versus homeowners, the net benefits of electrification reported in panels A and B are very similar. This may indicate that households expected the net effects of having a steam power plant built nearby to be permanent.

Regarding the net willingness to pay for new steam power plants, it is about $0.5 billion for counties with low rates of electrification, $0.3 billion for counties with medium rates, and -$3.7 billion for counties with high rates. As we can see, counties with broader access to electricity would have to be compensated for the pollution potentially generated in new thermal power plants. This is consistent with Davis' (2011) findings on the negative consequences of having fossil power plants built nearby, as mentioned previously.

In a landmark study, Chay and Greenstone (2005) show that, from 1970 to 1980, TSP concentration reduces by about $10\mu g/m^3$ in counties out of attainment under the Clean Air Act. More importantly, they find that this decline may have been capitalized into property values at a rate of about 0.28 percent per unit of TSP reduction. This implies that the willingness to pay for the late 1970s reductions in TSPs is approximately $45 billion (in 2001 dollars). Adjusting for the proportion of U.S. population included in our study (0.50 versus their 0.80), the share of coal consumption by electric utilities in our baseline (0.15 versus their 0.65), and the length of the period of our analysis (two decades versus their one decade), and correcting for inflation (1990 dollars versus their 2001 dollars), our estimate of the willingness to pay to avoid pollution arising from the burning of coal in the power sector is a bit more than a fourth of the one found by Chay and Greenstone (2005): $12.8 billion versus $45 billion (in 2001 dollars). Keeping only the net costs of electrification in

[18]Our results are not sensitive to using 80 or 120 years instead.

the calculation, which might reflect costs of air pollution only, our estimate jumps to $16.4 billion. Therefore, even excluding the amenity value of electricity, the valuation of air quality seems to be lower in the U.S. in the middle of the twentieth century.

6.5 Robustness Checks

In order to provide evidence that our results are not driven by the choice of variables used to classify counties into those nine bins, we run some robustness checks, which are reported in table 9. Besides lighting, one could measure access to electricity in the baseline by looking at the percentage of the households in a county with refrigerator or electric stove. We use lighting in the main specification because it is usually how households start enjoying the benefits of electricity. The acquisition of electrical appliances may depend more on household income, which might bias the estimates and make it harder the interpretation of the results. In our preferred specification, presented in the first column of table 9, we control for manufacturing payroll per worker, which is a proxy for income at the county level. This may attenuate the bias of using percentage of households with electrical appliances in the baseline to split counties into bins. Indeed, judging by the similarity of the patterns of the coefficients across the first three columns of table 9, our results do not seem sensitive to the way to define access to electricity in the baseline. Our covariates appear to be capturing well potential confounding factors related to income/wealth.

Another concern is regarding the salience of air pollution in the baseline. We use coal consumption per square mile because it may indicate well how pollutants are concentrated in a particular area. Identical coal consumption in Rhode Island and Montana would generate very different exposure to pollution when measured by coal consumption per square mile. However, we know that economic activity and, consequently, population, is not evenly distributed across space, so our measure of pollution may not reflect the true exposure faced by individuals. An alternative would be coal consumption per capita. This would convey the intensity of exposure to pollution independently of state size. Identical coal consumption in

Rhode Island and Montana would now generate very similar exposure to pollution. Despite completely different geographical areas (147,040 square miles versus 1,214 square miles), they have very similar population (1,015,165 versus 1,050,292). By noticing the similarities between the patterns and even point estimates of the first three and the last three columns of table 9, the way we choose to measure air pollution in the baseline does not appear to affect our results.

7 Concluding Remarks

This paper studies the costs and benefits of expansions to the thermal generation capacity. The empirical analysis exploits the historical rollout of U.S. thermal generating plants between 1940 and 1960, using newly digitized data on the timing of plant openings and thermal generation. We find that increases in thermal generation are associated with higher mortality rates, consistent with previous evidence on the health costs of fossil fuel emissions (see Currie et al., 2013). Results from hedonic housing price regressions suggest that these costs roughly offset the benefits associated with greater electricity access. Thermal capacity appears to offer diminishing net benefits to local residents, and the costs of pollution outweigh the welfare benefits associated with electricity access when electrification rates are high[19].

These findings offer several insights into current energy policy in the developing world[20]. First, it appears that households did perceive the health risks posed by thermal generation, even during a time period in which monitoring capabilities were nonexistent. It therefore seems unlikely that current policymakers will be able to ignore mounting public concerns regarding the health risks posed by thermal generation. Second, the results suggest that the optimal energy mix should depend not just on the availability of inputs, but also on the

[19]These results are consistent with Davis (2011), who finds negative net effects of fossil fuel power on local housing values in the 1990s – when electricity access was universal.

[20]According to the World Bank, over 1.2 billion people - 20 percent of the world's population - are still without access to electricity worldwide, almost all of whom live in developing countries.

stage of economic development. At low levels of consumption, expansions to thermal power capacity may offer net economic benefits by providing both households and firms access to low-cost electricity. As economies develop, the scope for these gains diminishes, and energy mix should shift towards cleaner (and potentially higher cost) sources of electricity. Given the longevity of generating capacity, policymakers must anticipate these changes when making decisions over electricity infrastructure investments in developing countries.

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Figure 1: Net Benefits of Steam Electricity

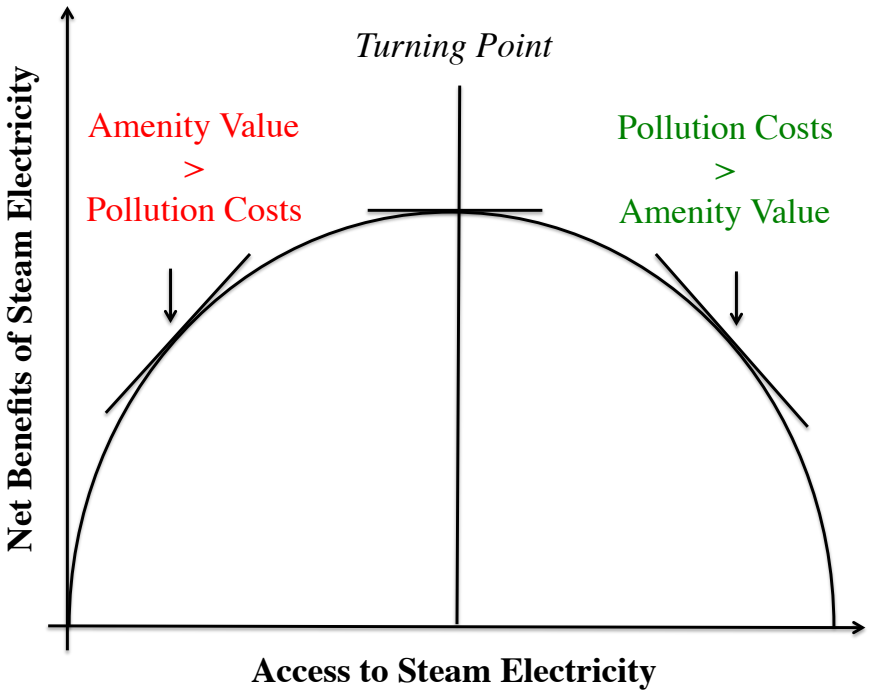
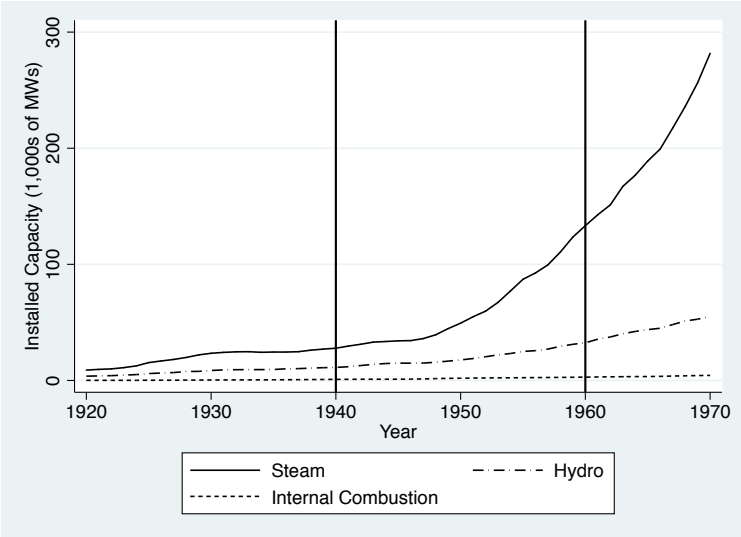
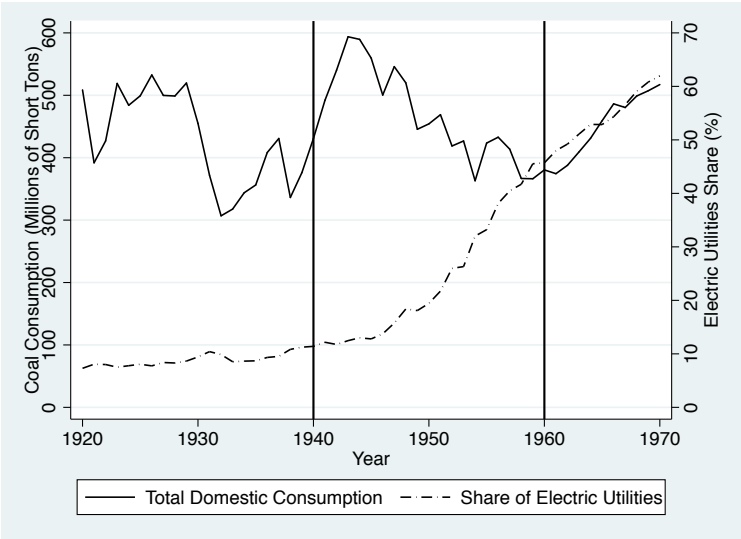


Figure 2: Total Installed Capacity



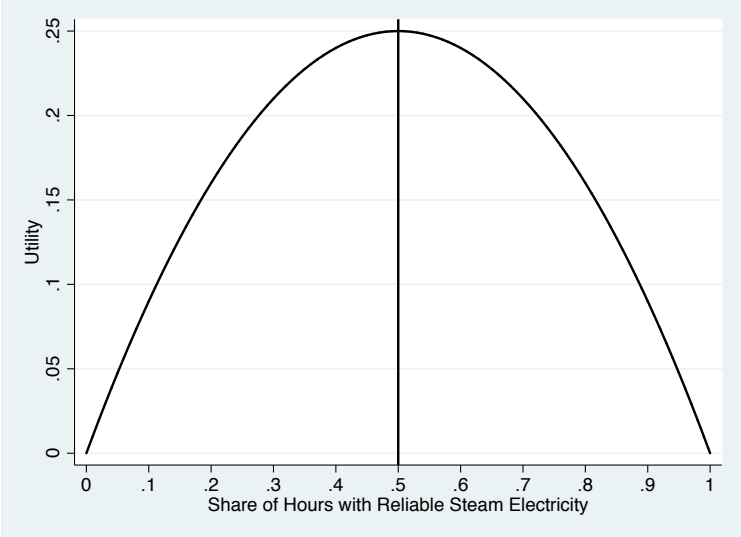
Source: Historical Statistics of the United States (1976).

Figure 3: Share of Electric Utilities in Domestic Coal Consumption Utility as a Function of Electricity



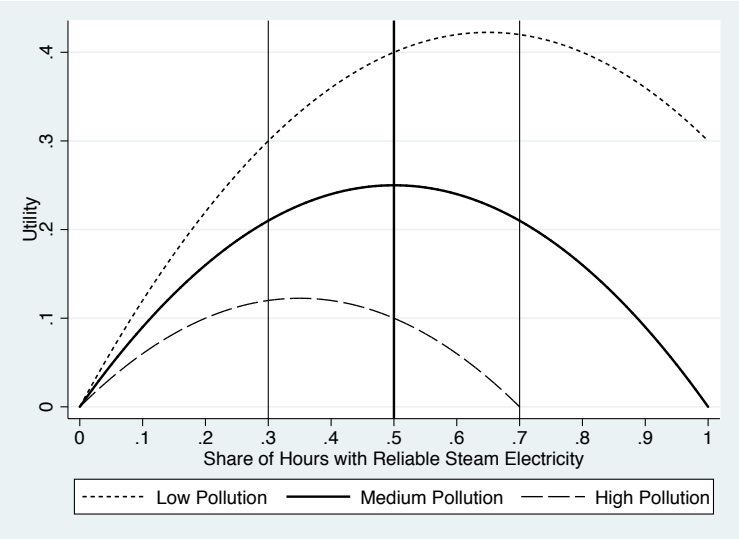
Source: Historical Statistics of the United States (1976).

Figure 4: Utility as a Function of Steam Electricity



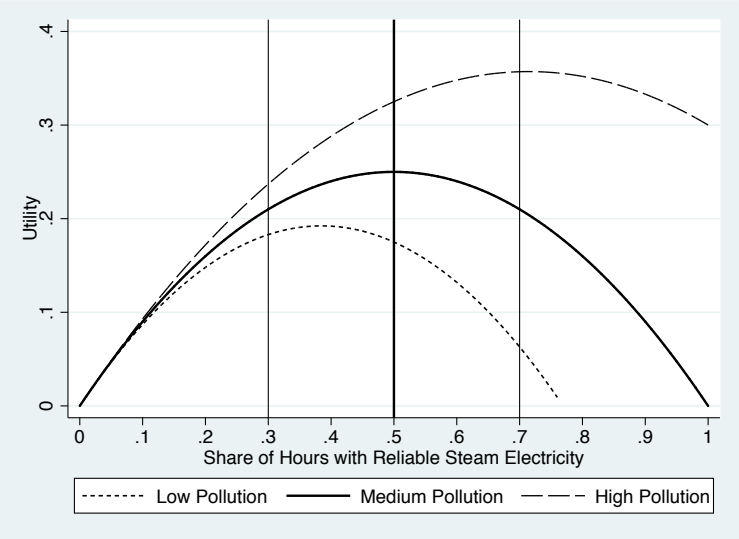
*Note*s: We are plotting the utility function $U(E) = E^{\alpha}(\theta - \delta E)^{\beta}$ using $\alpha = \beta = \theta = \delta = 1$. The thick solid vertical line is just emphasizing the turning point where the benefits of access to steam electricity are offset by the costs of pollution arising from thermal power generation.

Figure 5: Changing a_0 in the Utility Function



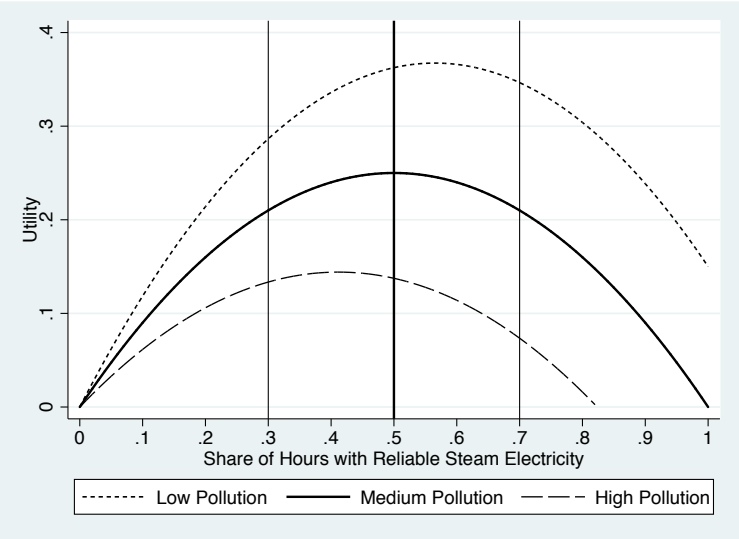
Notes: We are plotting the utility function $U(E) = E^{\alpha}(\theta - \delta E)^{\beta}$ using $\alpha = \beta = \delta = 1$. For low levels of pollution, we are assuming $\theta = 1.3$. For medium levels of pollution, we are assuming $\theta = 1$. For high levels of pollution, we are assuming $\theta = 0.7$. The thick solid vertical line is just emphasizing the turning point for the medium case, where the benefits of access to steam electricity are offset by the costs of pollution arising from thermal power generation. The thin solid lines are just cutting the graphs to facilitate the comparison of marginal utilities for different levels of pollution.

Figure 6: Changing a_1 in the Utility Function



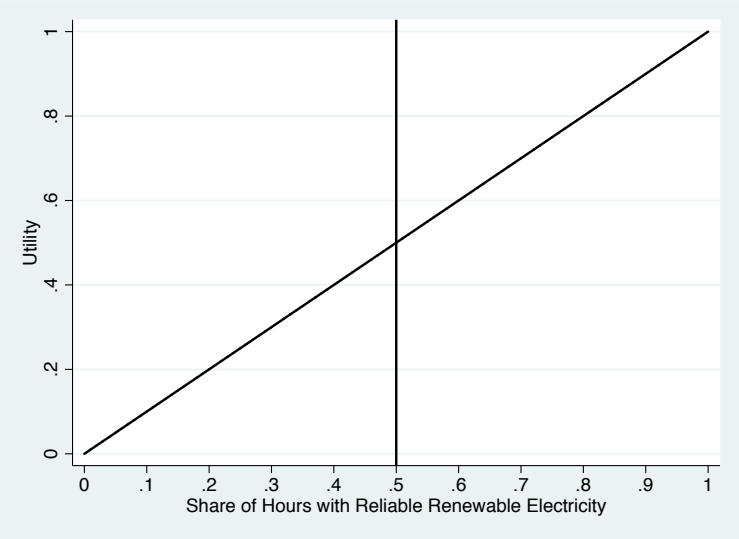
Notes: We are plotting the utility function $U(E) = E^{\alpha}(\theta - \delta E)^{\beta}$ using $\alpha = \beta = \theta = 1$. For low levels of pollution, we are assuming $\delta = 1.3$. For medium levels of pollution, we are assuming $\delta = 1$. For high levels of pollution, we are assuming $\delta = 0.7$. The thick solid vertical line is just emphasizing the turning point for the medium case, where the benefits of access to steam electricity are offset by the costs of pollution arising from thermal power generation. The thin solid lines are just cutting the graphs to facilitate the comparison of marginal utilities for different levels of pollution.

Figure 7: Changing h_1 in the Utility Function



Notes: We are plotting the utility function $U(E) = E^{\alpha}(\theta - \delta E)^{\beta}$ using $\alpha = \beta = 1$. For low levels of pollution, we are assuming $\theta = 1.3$ and $\delta = 1.15$. For medium levels of pollution, we are assuming $\theta = \delta = 1$. For high levels of pollution, we are assuming $\theta = 0.7$ and $\delta = 0.85$. The thick solid vertical line is just emphasizing the turning point for the medium case, where the benefits of access to steam electricity are offset by the costs of pollution arising from thermal power generation. The thin solid lines are just cutting the graphs to facilitate the comparison of marginal utilities for different levels of pollution.

Figure 8: Utility as a Function of Renewable Electricity



Notes: We are plotting the utility function $U(E) = E^{\alpha}(\theta - \delta E)^{\beta}$ using $\alpha = \beta = \theta = 1$ and $\delta = 0$. The thick solid vertical line was the turning point where the benefits of access to steam electricity are offset by the costs of pollution arising from thermal power generation. There is no turning point for the case of renewable energy.

Figure 9: Counties in Our Sample

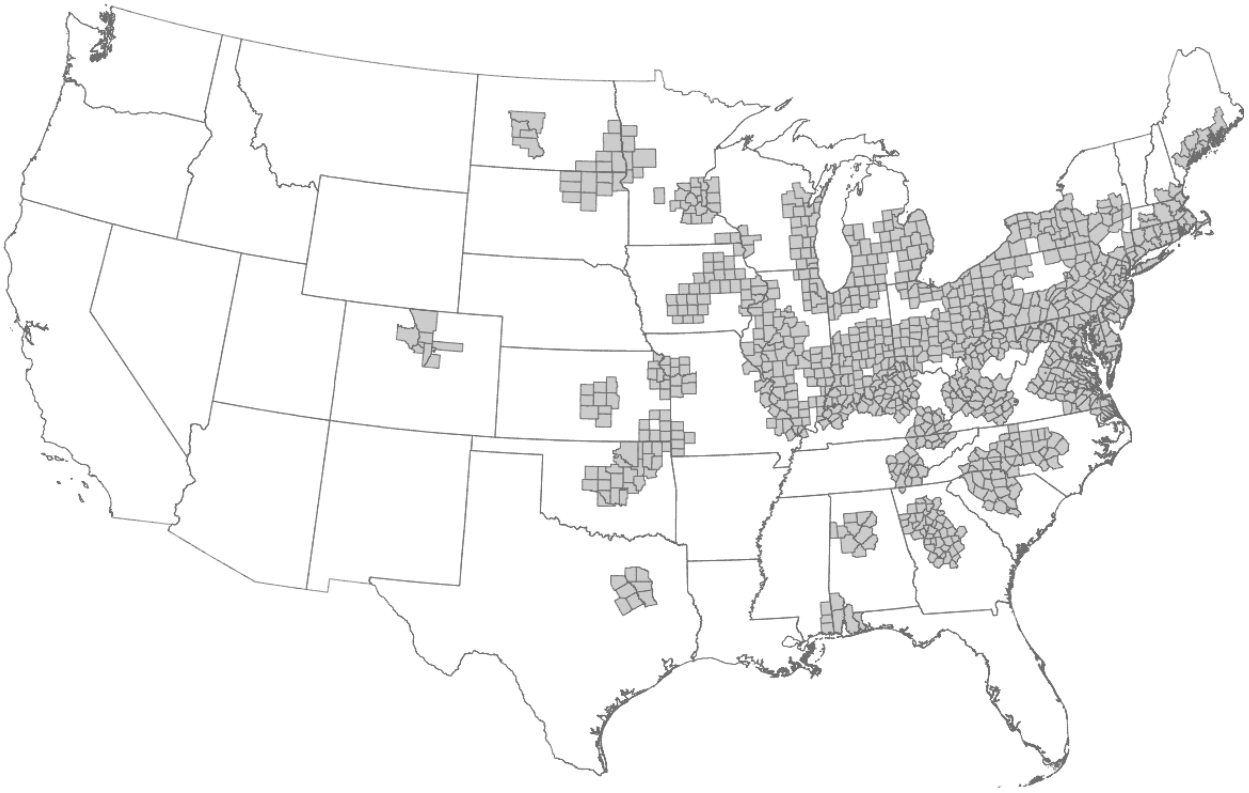
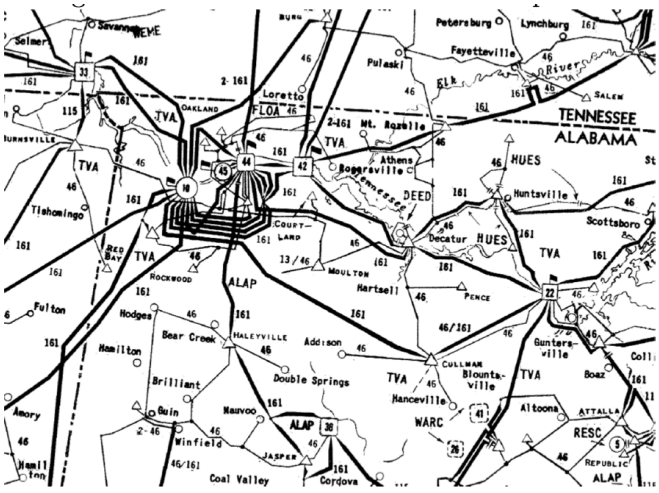
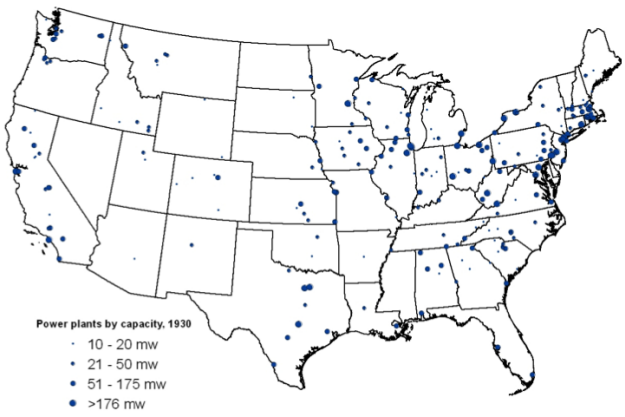


Figure 10: Federal Power Commission Map: 1962

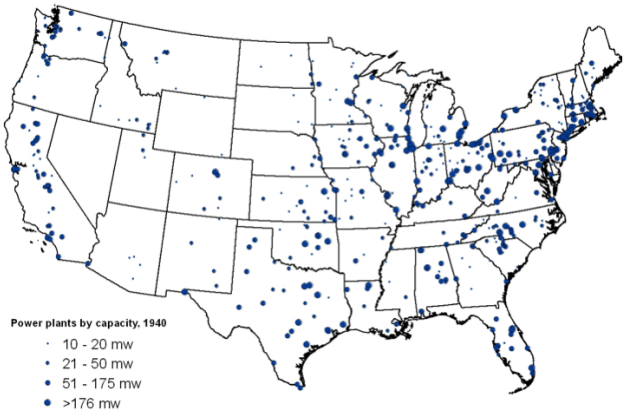


Source: U.S. Federal Power Comission (1963).

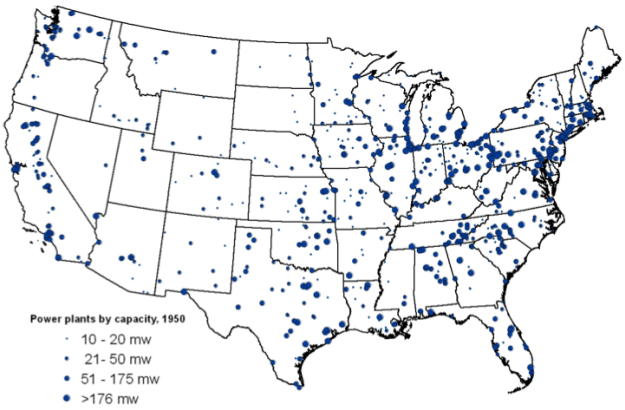
Figure 11: U.S. Power Plants: 1930 to 1960



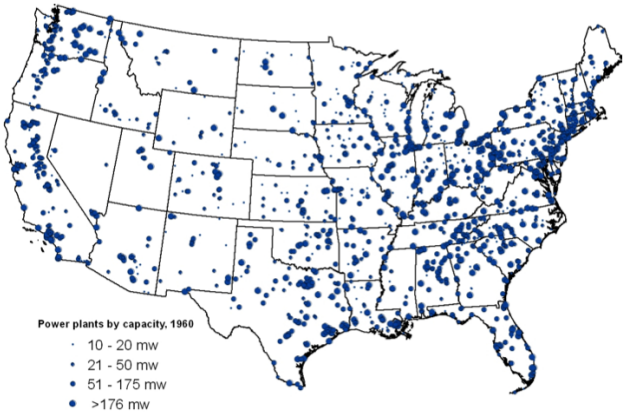
(a) 1930



(b) 1940



(c) 1950



(d) 1960

Table 1: 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 2: Estimates of Total Suspended Particulates (TSP)

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)
US Urban Stations	1960	118	Lave and Seskin (1972)
US National Average	1990	60	Chay and Greenstone (2003)
58 Chinese Cities	1980-1993	538	Almond et al. (2009)
Worldwide	1999	18% of urban pop > 240	Cohen et al. (2004)

Notes: From Barreca, Clay, and Tarr (2014). 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 percent of the urban population lived in locations where thePM_{10} was greater than 100. We translated the PM_{10} values to TSP using the following formula: PM_{10} /0.417, where 0.417 is the empirical ratio of PM_{10} to TSP in their world data (Table 17.4). The estimate for 1990 is from Chay and Greenstone (2003), Figure 1.

Table 3: Summary Statistics - Bins

Bins: PHHL1940 x CCSM1927			Number of Counties	Percentage of HH w/ Lighting (1940)	Coal Cons. Per Sq.Mi. (Net Tons) (1927)
L-PHHL1940	x	H-CCSM1927	32	35.91	462.02
L-PHHL1940	x	M-CCSM1927	68	32.80	99.33
L-PHHL1940	x	L-CCSM1927	85	26.89	15.56
M-PHHL1940	x	H-CCSM1927	81	62.30	634.63
M-PHHL1940	x	M-CCSM1927	128	59.38	98.45
M-PHHL1940	x	L-CCSM1927	63	60.30	24.31
H-PHHL1940	x	H-CCSM1927	254	87.85	772.32
H-PHHL1940	x	M-CCSM1927	72	82.22	96.84
H-PHHL1940	x	L-CCSM1927	41	84.78	24.55
Total			824	65.32	355.03

Notes: $PHHL1940$ stands for Percentage of Households with Lighting in the baseline (1940), and $CCSM1927$ for Coal Consumption Per Square Mile in the baseline (1927). H, M, and L stand for High, Medium, and Low, respectively, and represent bins for the top, middle, and bottom tercile of the distribution. In constructing these bins, the 33th percentile of $PHHL1940$ was 45.6 percent, and the 66th percentile was 72.9 percent. Similar numbers for $CCSM1927$ are 42.84 and 159.56 net tons of bituminous coal consumed per square mile.

Table 4: Summary Statistics

	Number of Counties	Total Population (1000s)	Total Population (%)	Average Population (1000s)	Number of Dwellings (1000s)	Median Dwelling Value ($1990)	Median Dwelling Rent ($1990)	DistPP50 (Miles)	DistPP50 Steam (Miles)	DistPP50 Hydro (Miles)
Panel A. 1940										
L-PHHL1940 x H-CCSM1927	32	556	0.9	17	144	11,606	62	47	55	82
L-PHHL1940 x M-CCSM1927	68	1,636	2.7	24	392	12,684	63	61	71	91
L-PHHL1940 x L-CCSM1927	85	2,085	3.4	25	536	8,416	51	69	81	182
M-PHHL1940 x H-CCSM1927	81	1,946	3.2	24	546	14,641	94	40	42	105
M-PHHL1940 x M-CCSM1927	128	3,376	5.5	26	856	17,128	103	69	78	130
M-PHHL1940 x L-CCSM1927	63	1,710	2.8	27	491	13,542	99	70	77	213
H-PHHL1940 x H-CCSM1927	254	38,113	62.5	150	10,789	27,048	172	29	30	138
H-PHHL1940 x M-CCSM1927	72	4,255	7.0	59	1,259	23,776	162	61	66	162
H-PHHL1940 x L-CCSM1927	41	7,338	12.0	179	2,349	22,376	160	46	57	181
Total	824	61,015	100.0	74	17,362	19,029	121	51	56	142
Panel B. 1960-1940										
L-PHHL1940 x H-CCSM1927	32	-44	-0.3	-1	20	15,067	137	-23	-30	-10
L-PHHL1940 x M-CCSM1927	68	15	-0.8	0	100	16,489	133	-29	-37	-25
L-PHHL1940 x L-CCSM1927	85	-72	-1.1	-1	72	18,794	117	-42	-53	-32
M-PHHL1940 x H-CCSM1927	81	247	-0.7	3	172	17,609	152	-16	-18	-9
M-PHHL1940 x M-CCSM1927	128	672	-0.9	6	374	18,569	152	-36	-43	-34
M-PHHL1940 x L-CCSM1927	63	416	-0.4	7	225	19,967	148	-39	-38	-59
H-PHHL1940 x H-CCSM1927	254	14,405	-2.8	57	5,950	21,309	136	-10	-11	-13
H-PHHL1940 x M-CCSM1927	72	2,192	0.3	31	829	24,010	148	-32	-36	-50
H-PHHL1940 x L-CCSM1927	41	9,191	6.7	224	3,248	26,755	149	-20	-30	-25
Total	824	27,022	0.0	33	10,990	20,025	140	-25	-29	-26
Panel C. 1960-1940					**Percentage Change**					
L-PHHL1940 x H-CCSM1927	32	-8	-36.2	-6	14	130	221	-49	-55	-12
L-PHHL1940 x M-CCSM1927	68	1	-30.1	0	26	130	211	-48	-52	-27
L-PHHL1940 x L-CCSM1927	85	-3	-33.1	-4	13	223	229	-61	-65	-18
M-PHHL1940 x H-CCSM1927	81	13	-21.9	13	32	120	162	-40	-43	-9
M-PHHL1940 x M-CCSM1927	128	20	-16.9	23	44	108	148	-52	-55	-26
M-PHHL1940 x L-CCSM1927	63	24	-13.8	26	46	147	149	-56	-49	-28
H-PHHL1940 x H-CCSM1927	254	38	-4.5	38	55	79	79	-34	-37	-9
H-PHHL1940 x M-CCSM1927	72	52	5.0	53	66	101	91	-52	-55	-31
H-PHHL1940 x L-CCSM1927	41	125	56.1	125	138	120	93	-43	-53	-14
Total	824	44	0.0	45	63	105	116	-49	-52	-18

Notes: $DistPP50$ is the distance to the nearest power plant with at least 50 megawatts of capacity. $PHHL1940$ stands for Percentage of Households with Lighting in the baseline (1940), and $CCSM1927$ for Coal Consumption Per Square Mile in the baseline (1927). H, M, and L stand for High, Medium, and Low, respectively, and represent bins for the top, middle, and bottom tercile of the distribution.

Table 5: Infant Mortality Effects

Dep. Variable: Infant Mortality Rate	Year FE + County FE	+ State Trend	+ Geography	+ Economy	- State Trend + State-Year FE
Indep. Variables (measured within 50 Miles)	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
Coal Consumption (in 100,000s of tons)	0.0855***	0.0498**	0.0468**	0.0477**	0.0387*
	[0.0233]	[0.0208]	[0.0202]	[0.0199]	[0.0220]
Net Generation (in 100 millions of kWh)	0.0851***	0.0638*	0.0717**	0.0768**	0.0731*
	[0.0249]	[0.0344]	[0.0348]	[0.0353]	[0.0390]
Steam Capacity (in MW)	0.00220	0.00180	0.00288	0.00360	0.00481*
	[0.00191]	[0.00247]	[0.00252]	[0.00248]	[0.00265]
Plant Hours Connected to Grid x	0.000387***	0.000239**	0.000287**	0.000275**	0.000297**
x Steam Capacity (in 10,000s of MWs)	[8.54e-05]	[0.000113]	[0.000113]	[0.000122]	[0.000126]
Observations	11,361	11,361	11,152	10,634	10,634
R-squared	0.463	0.483	0.487	0.515	0.538
Number of Counties	961	961	947	901	901

Notes: Each coefficient comes from a different regression with Infant Mortality Rate (per 1,000 live births) as the dependent variable. R-squared's are similar across regressions in each column, so we report only one in each column. All regressions include county and year fixed effects. "Geography" covariates include time-varying controls for 10-year moving averages for precipitation, temperature, degree days below 10C, and degree days above 29C, and latitude and longitude interacted with year. "Economy" covariates include total employment, manufacturing employment, and manufacturing payroll per worker at the baseline (1940), all interacted with year. Standard errors are clustered at the county-level. ***,**,* denote significance at the 1%, 5%, and 10% level, respectively.

Table 6: Net Benefits of Electrification - Average Effects

Model Specification	Year FE + County FE	+ State Trend	+ Geography	+ Economy	- State Trend + State-Year FE
	(1)	**(2)**	**(3)**	**(4)**	**(5)**
Panel A. Median Dwelling Rent (Renter-Occupied)					
DistPP50Steam	0.0126***	0.0041	0.0017	0.0007	0.0003
	(0.0030)	(0.0028)	(0.0032)	(0.0030)	(0.0033)
Observations	2,472	2,472	2,472	2,472	2,472
R-squared	0.9207	0.9477	0.9499	0.9588	0.9614
Panel B. Median Dwelling Value (Owner-Occupied)					
DistPP50Steam	0.0154***	0.0039	0.0049	0.0046	0.0040
	(0.0029)	(0.0030)	(0.0033)	(0.0033)	(0.0038)
Observations	2,472	2,472	2,472	2,472	2,472
R-squared	0.9283	0.9534	0.9563	0.9570	0.9584

Notes: $DistPP50Steam$ is the distance to the nearest steam power plant with at least 50 megawatts of capacity. All regressions include county and year fixed effects. "Geography" covariates include time-varying controls for 10-year moving averages for precipitation, temperature, degree days below 10C, and degree days above 29C, and latitude and longitude interacted with year. "Economy" covariates include total employment, manufacturing employment, and manufacturing payroll per worker at the baseline (1940), all interacted with year. Standard errors are clustered at the county-level. ***,**,* denote significance at the 1%, 5%, and 10% level, respectively.

Table 7: Net Benefits of Electrification - Main Results

Model Specification	Year FE + County FE (1)	+ State Trend (2)	+ Geography (3)	+ Economy (4)	- State Trend + State-Year FE (5)
Panel A. Median Dwelling Rent (Renter-Occupied)					
DistPP50Steam x L-PHHL1940 x H-CCSM1927	0.0761***	0.0648***	0.0592***	0.0447***	0.0505***
	(0.0132)	(0.0160)	(0.0168)	(0.0152)	(0.0147)
DistPP50Steam x L-PHHL1940 x M-CCSM1927	0.0479***	0.0242***	0.0233***	0.0209***	0.0181**
	(0.0088)	(0.0065)	(0.0065)	(0.0065)	(0.0072)
DistPP50Steam x L-PHHL1940 x L-CCSM1927	0.0426***	0.0169***	0.0089	0.0064	0.0020
	(0.0053)	(0.0062)	(0.0065)	(0.0066)	(0.0072)
DistPP50Steam x M-PHHL1940 x H-CCSM1927	0.0310**	0.0362***	0.0368***	0.0293***	0.0314***
	(0.0121)	(0.0126)	(0.0110)	(0.0088)	(0.0094)
DistPP50Steam x M-PHHL1940 x M-CCSM1927	0.0010	-0.0010	-0.0012	-0.0011	-0.0025
	(0.0034)	(0.0035)	(0.0034)	(0.0034)	(0.0036)
DistPP50Steam x M-PHHL1940 x L-CCSM1927	0.0098*	-0.0109**	-0.0173***	-0.0160***	-0.0190***
	(0.0051)	(0.0054)	(0.0057)	(0.0054)	(0.0068)
DistPP50Steam x H-PHHL1940 x H-CCSM1927	-0.0462***	-0.0167	-0.0115	-0.0111	-0.0099
	(0.0143)	(0.0120)	(0.0120)	(0.0113)	(0.0115)
DistPP50Steam x H-PHHL1940 x M-CCSM1927	-0.0195***	-0.0151**	-0.0171**	-0.0143**	-0.0160**
	(0.0053)	(0.0064)	(0.0068)	(0.0064)	(0.0066)
DistPP50Steam x H-PHHL1940 x L-CCSM1927	-0.0115**	-0.0261***	-0.0346***	-0.0291***	-0.0307***
	(0.0052)	(0.0055)	(0.0059)	(0.0062)	(0.0068)
Observations	2,472	2,472	2,472	2,472	2,472
R-squared	0.9341	0.9520	0.9540	0.9615	0.9640
Panel B. Median Dwelling Value (Owner-Occupied)					
DistPP50Steam x L-PHHL1940 x H-CCSM1927	0.0538***	0.0524***	0.0487***	0.0462***	0.0495***
	(0.0199)	(0.0158)	(0.0140)	(0.0144)	(0.0157)
DistPP50Steam x L-PHHL1940 x M-CCSM1927	0.0241**	0.0223**	0.0238**	0.0238**	0.0221**
	(0.0112)	(0.0110)	(0.0104)	(0.0104)	(0.0110)
DistPP50Steam x L-PHHL1940 x L-CCSM1927	0.0490***	0.0137*	0.0095	0.0084	0.0078
	(0.0066)	(0.0076)	(0.0074)	(0.0073)	(0.0086)
DistPP50Steam x M-PHHL1940 x H-CCSM1927	0.0136*	0.0190***	0.0218***	0.0209**	0.0223***
	(0.0072)	(0.0064)	(0.0079)	(0.0083)	(0.0080)
DistPP50Steam x M-PHHL1940 x M-CCSM1927	-0.0008	-0.0034	0.0003	0.0006	-0.0033
	(0.0034)	(0.0032)	(0.0036)	(0.0037)	(0.0041)
DistPP50Steam x M-PHHL1940 x L-CCSM1927	0.0160***	-0.0053	-0.0090	-0.0092	-0.0095
	(0.0057)	(0.0079)	(0.0070)	(0.0068)	(0.0084)
DistPP50Steam x H-PHHL1940 x H-CCSM1927	-0.0314**	-0.0067	0.0030	0.0028	0.0034
	(0.0159)	(0.0112)	(0.0121)	(0.0123)	(0.0126)
DistPP50Steam x H-PHHL1940 x M-CCSM1927	-0.0060	-0.0081*	-0.0065*	-0.0061	-0.0102**
	(0.0048)	(0.0043)	(0.0038)	(0.0038)	(0.0041)
DistPP50Steam x H-PHHL1940 x L-CCSM1927	0.0102	-0.0153**	-0.0190***	-0.0184***	-0.0171**
	(0.0063)	(0.0064)	(0.0062)	(0.0064)	(0.0082)
Observations	2,472	2,472	2,472	2,472	2,472
R-squared	0.9361	0.9555	0.9581	0.9587	0.9601

Notes: $DistPP50Steam$ is the distance to the nearest steam power plant with at least 50 megawatts of capacity. $PHHL1940$ stands for Percentage of Households with Lighting in the baseline (1940), and $CCSM1927$ for Coal Consumption Per Square Mile in the baseline (1927). H, M, and L stand for High, Medium, and Low, respectively, and represent bins for the top, middle, and bottom tercile of the distribution. All regressions include county and year fixed effects. "Geography" covariates include time-varying controls for 10-year moving averages for precipitation, temperature, degree days below 10C, and degree days above 29C, and latitude and longitude interacted with year. "Economy" covariates include total employment, manufacturing employment, and manufacturing payroll per worker at the baseline (1940), all interacted with year. Standard errors are clustered at the county-level. ***,**,* denote significance at the 1%, 5%, and 10% level, respectively.

Table 8: Net Benefits of Electrification - Interpretation and Welfare Calculations

Main Results	Number of Counties	Population 1940 (1000s)	Number of Dwellings (1000s)	Median Rent/Value 1940 ($1990)	ΔDistPP50 Steam 1960-1940 (Miles)	Coefficients of Preferred Specification	Coefficients x ΔDistPP50	Effects Weighted by # of Dwellings ($1990) (Millions)	Sum of Significant Effects ($1990) (Millions)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A. Median Dwelling Rent (Renter-Occupied)									
DistPP50Steam x L-PHHL1940 x H-CCSM1927	32	556	144	62	-30	0.0505***	0.1515	57.63	
						(0.0147)			
DistPP50Steam x L-PHHL1940 x M-CCSM1927	68	1,636	392	63	-37	0.0181**	0.06697	54.09	111.72
						(0.0072)			
DistPP50Steam x L-PHHL1940 x L-CCSM1927	85	2,085	536	51	-53	0.0020	0.0106	6.44	
						(0.0072)			
DistPP50Steam x M-PHHL1940 x H-CCSM1927	81	1,946	546	94	-18	0.0314***	0.05652	199.41	
						(0.0094)			
DistPP50Steam x M-PHHL1940 x M-CCSM1927	128	3,376	856	103	-43	-0.0025	-0.01075	-25.77	94.29
						(0.0036)			
DistPP50Steam x M-PHHL1940 x L-CCSM1927	63	1,710	491	99	-38	-0.0190***	-0.0722	-105.12	
						(0.0068)			
DistPP50Steam x H-PHHL1940 x H-CCSM1927	254	38,113	10,789	172	-11	-0.0099	-0.01089	-2,122.23	
						(0.0115)			
DistPP50Steam x H-PHHL1940 x M-CCSM1927	72	4,255	1,259	162	-36	-0.0160**	-0.0576	-373.24	-1,661.86
						(0.0066)			
DistPP50Steam x H-PHHL1940 x L-CCSM1927	41	7,338	2,349	160	-30	-0.0307***	-0.0921	-1,288.62	
						(0.0068)			
Total	824	61,015	17,362	121	-29				-1,455.84
Panel B. Median Dwelling Value (Owner-Occupied)									
DistPP50Steam x L-PHHL1940 x H-CCSM1927	32	556	144	11,606	-30	0.0495***	0.1485	132.78	
						(0.0157)			
DistPP50Steam x L-PHHL1940 x M-CCSM1927	68	1,636	392	12,684	-37	0.0221**	0.08177	217.52	350.29
						(0.0110)			
DistPP50Steam x L-PHHL1940 x L-CCSM1927	85	2,085	536	8,416	-53	0.0078	0.04134	99.77	
						(0.0086)			
DistPP50Steam x M-PHHL1940 x H-CCSM1927	81	1,946	546	14,641	-18	0.0223***	0.04014	171.67	
						(0.0080)			
DistPP50Steam x M-PHHL1940 x M-CCSM1927	128	3,376	856	17,128	-43	-0.0033	-0.01419	-111.31	171.67
						(0.0041)			
DistPP50Steam x M-PHHL1940 x L-CCSM1927	63	1,710	491	13,542	-38	-0.0095	-0.0361	-128.42	
						(0.0084)			
DistPP50Steam x H-PHHL1940 x H-CCSM1927	254	38,113	10,789	27,048	-11	0.0034	0.00374	583.90	
						(0.0126)			
DistPP50Steam x H-PHHL1940 x M-CCSM1927	72	4,255	1,259	23,776	-36	-0.0102**	-0.03672	-588.06	-2,030.63
						(0.0041)			
DistPP50Steam x H-PHHL1940 x L-CCSM1927	41	7,338	2,349	22,376	-30	-0.0171**	-0.0513	-1,442.57	
						(0.0082)			
Total	824	61,015	17,362	19,029	-29				-1,508.66
Total: Rent + Value									-2,964.51

Notes: $DistPP50Steam$ is the distance to the nearest steam power plant with at least 50 megawatts of capacity. $PHHL1940$ stands for Percentage of Households with Lighting in the baseline (1940), and $CCSM1927$ for Coal Consumption Per Square Mile in the baseline (1927). H, M, and L stand for High, Medium, and Low, respectively, and represent bins for the top, middle, and bottom tercile of the distribution. ***,**,* denote significance at the 1%, 5%, and 10% level, respectively.

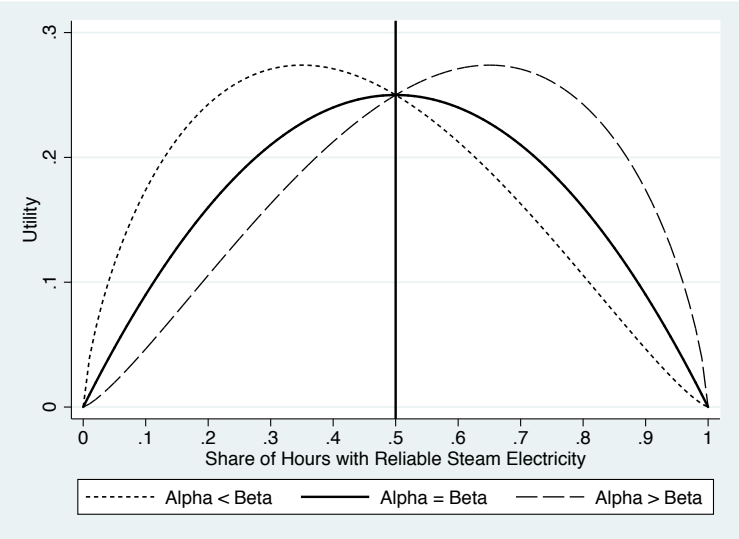
Table 9: Net Benefits of Electrification - Robustness Checks

Interactions: Coal Consumption x Power Access	CCSM x Light	CCSM x Refrig	CCSM x Stove	CCPC x Light	CCPC x Refrig	CCPC x Stove
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Median Dwelling Rent (Renter-Occupied)						
DistPP50Steam x L-PHH_1940 x H-CC_1927	0.0505***	0.0431***	0.0371***	0.0477***	0.0401***	0.0248***
	(0.0147)	(0.0101)	(0.0124)	(0.0156)	(0.0097)	(0.0081)
DistPP50Steam x L-PHH_1940 x M-CC_1927	0.0181**	0.0098*	0.0124**	0.0147*	0.0062	0.0113*
	(0.0072)	(0.0055)	(0.0056)	(0.0081)	(0.0059)	(0.0068)
DistPP50Steam x L-PHH_1940 x L-CC_1927	0.0020	0.0083	0.0102*	0.0077	0.0123**	0.0141**
	(0.0072)	(0.0055)	(0.0056)	(0.0067)	(0.0058)	(0.0061)
DistPP50Steam x M-PHH_1940 x H-CC_1927	0.0314***	0.0275***	0.0336***	0.0202***	0.0156**	0.0168*
	(0.0094)	(0.0084)	(0.0078)	(0.0077)	(0.0078)	(0.0096)
DistPP50Steam x M-PHH_1940 x M-CC_1927	-0.0025	0.0011	-0.0043	-0.0015	0.0043	-0.0004
	(0.0036)	(0.0038)	(0.0033)	(0.0046)	(0.0052)	(0.0048)
DistPP50Steam x M-PHH_1940 x L-CC_1927	-0.0190***	-0.0096	-0.0014	-0.0192***	-0.0088	-0.0029
	(0.0068)	(0.0101)	(0.0068)	(0.0062)	(0.0080)	(0.0063)
DistPP50Steam x H-PHH_1940 x H-CC_1927	-0.0099	-0.0203**	-0.0256***	-0.0096	-0.0193*	-0.0316***
	(0.0115)	(0.0089)	(0.0086)	(0.0098)	(0.0099)	(0.0099)
DistPP50Steam x H-PHH_1940 x M-CC_1927	-0.0160**	-0.0276***	-0.0254*	-0.0223**	-0.0232***	-0.0215*
	(0.0066)	(0.0095)	(0.0137)	(0.0094)	(0.0081)	(0.0112)
DistPP50Steam x H-PHH_1940 x L-CC_1927	-0.0307***	-0.0340***	-0.0246***	-0.0309***	-0.0361***	-0.0240***
	(0.0068)	(0.0072)	(0.0070)	(0.0070)	(0.0076)	(0.0074)
Observations	2,472	2,472	2,472	2,472	2,472	2,472
R-squared	0.9640	0.9648	0.9650	0.9636	0.9643	0.9641
Panel B. Median Dwelling Value (Owner-Occupied)						
DistPP50Steam x L-PHH_1940 x H-CC_1927	0.0495***	0.0468***	0.0426***	0.0496***	0.0462***	0.0296**
	(0.0157)	(0.0126)	(0.0119)	(0.0176)	(0.0129)	(0.0119)
DistPP50Steam x L-PHH_1940 x M-CC_1927	0.0221**	0.0127	0.0120	0.0275**	0.0133*	0.0124*
	(0.0110)	(0.0081)	(0.0074)	(0.0116)	(0.0077)	(0.0068)
DistPP50Steam x L-PHH_1940 x L-CC_1927	0.0078	0.0051	0.0170*	0.0100	0.0100	0.0170*
	(0.0086)	(0.0096)	(0.0092)	(0.0088)	(0.0100)	(0.0097)
DistPP50Steam x M-PHH_1940 x H-CC_1927	0.0223***	0.0175*	0.0220*	0.0175*	0.0119	0.0142
	(0.0080)	(0.0100)	(0.0118)	(0.0098)	(0.0110)	(0.0128)
DistPP50Steam x M-PHH_1940 x M-CC_1927	-0.0033	-0.0020	-0.0052	-0.0000	0.0033	-0.0019
	(0.0041)	(0.0043)	(0.0040)	(0.0052)	(0.0057)	(0.0060)
DistPP50Steam x M-PHH_1940 x L-CC_1927	-0.0095	0.0023	-0.0041	-0.0099	-0.0016	-0.0045
	(0.0084)	(0.0111)	(0.0084)	(0.0078)	(0.0086)	(0.0078)
DistPP50Steam x H-PHH_1940 x H-CC_1927	0.0034	-0.0049	-0.0088	0.0018	-0.0065	-0.0124
	(0.0126)	(0.0069)	(0.0070)	(0.0113)	(0.0059)	(0.0084)
DistPP50Steam x H-PHH_1940 x M-CC_1927	-0.0102**	-0.0113**	-0.0024	-0.0130*	-0.0111*	-0.0039
	(0.0041)	(0.0047)	(0.0110)	(0.0074)	(0.0064)	(0.0106)
DistPP50Steam x H-PHH_1940 x L-CC_1927	-0.0171**	-0.0131	-0.0093	-0.0169*	-0.0134	-0.0090
	(0.0082)	(0.0082)	(0.0075)	(0.0088)	(0.0090)	(0.0082)
Observations	2,472	2,472	2,472	2,472	2,472	2,472
R-squared	0.9601	0.9599	0.9603	0.9599	0.9598	0.9598

Notes: $DistPP50Steam$ is the distance to the nearest steam power plant with at least 50 megawatts of capacity. PHH_1940 stands for Percentage of Households with some access toe electricity at the baseline (1940), and the underscore should be replaced with the bottom variable in the column labels: Lighting, Refrigerator or Stove. CC_1927 stands for Coal Consumption at the baseline (1927), and the underscore should be replaced with the last two letters of the top variable in the column labels: SM-Per Square Mile or PC-Per Capita. H, M, and L stand for High, Medium, and Low, respectively, and represent bins for the top, middle, and bottom tercile of the distribution. All regressions include county and state-year fixed effects, "geography" covariates (time-varying controls for 10-year moving averages for precipitation, temperature, degree days below 10C, and degree days above 29C, and latitude and longitude interacted with year), and "economy" covariates (total employment, manufacturing employment, and manufacturing payroll per worker at the baseline (1940), all interacted with year). Standard errors are clustered at the county-level. ***,**,* denote significance at the 1%, 5%, and 10% level, respectively.

Appendix

Figure A.1: Utility as a Function of Steam Electricity - Changes in Preferences



Notes: We are plotting the utility function $U(E) = E^{\alpha}(\theta - \delta E)^{\beta}$ using $\alpha = \beta = \theta = \delta = 1$ for the solid thick graph, $\alpha = 0.7$, $\beta = 1.3$, and $\theta = \delta = 1$ for the short-dashed graph, and $\alpha = 1.3$, $\beta = 0.7$, and $\theta = \delta = 1$ for the long-dashed graph.

Table A.1: Summary Statistics: "Geography" Covariates - 1940

Bins: PHHL1940 x CCSM1927	Number of Counties	Latitude	Longitude	Total Precipitation (millimeters)	Average Temperature (Celsius)	Degree Days Above 29C	Degree Days Below 10C
				(10-Year Moving Averages)		(10-Year Moving Averages)	
L-PHHL1940 x H-CCSM1927	32	37.37	-84.89	1,129.20	13.32	4.08	1,008.59
L-PHHL1940 x M-CCSM1927	68	37.04	-83.60	1,101.50	14.10	5.35	881.53
L-PHHL1940 x L-CCSM1927	85	32.66	-92.29	1,303.38	18.09	21.57	377.74
M-PHHL1940 x H-CCSM1927	81	39.23	-84.51	1,029.71	12.00	3.83	1,270.73
M-PHHL1940 x M-CCSM1927	128	40.01	-88.89	927.45	11.03	4.80	1,549.85
M-PHHL1940 x L-CCSM1927	63	36.45	-94.88	939.79	14.88	22.97	965.62
H-PHHL1940 x H-CCSM1927	254	41.03	-80.95	980.75	10.15	1.68	1,576.21
H-PHHL1940 x M-CCSM1927	72	41.96	-89.57	850.72	9.18	2.96	1,917.64
H-PHHL1940 x L-CCSM1927	41	36.25	-100.98	801.49	15.15	29.49	777.19
Total	824	38.85	-86.89	1,002.88	12.26	7.95	1,282.48

Table A.2: Summary Statistics: "Economy" Covariates - 1940

Bins: PHHL1940 x CCSM1927	Number of Counties	Total Employment	*Average Employment*	Total Employment in Manufacturing	*Average Employment in Manufacturing*	Average Mfg. Payroll Per Worker
		(1000s)	*(1000s)*	(1000s)	*(1000s)*	
L-PHHL1940 x H-CCSM1927	32	161	*5.0*	19	*0.6*	4.21
L-PHHL1940 x M-CCSM1927	68	500	*7.4*	61	*0.9*	4.74
L-PHHL1940 x L-CCSM1927	85	710	*8.4*	55	*0.7*	4.93
M-PHHL1940 x H-CCSM1927	81	571	*7.1*	88	*1.1*	6.26
M-PHHL1940 x M-CCSM1927	128	1,110	*8.7*	177	*1.4*	8.29
M-PHHL1940 x L-CCSM1927	63	554	*8.8*	54	*0.9*	7.16
H-PHHL1940 x H-CCSM1927	254	13,639	*53.7*	4,598	*18.1*	9.96
H-PHHL1940 x M-CCSM1927	72	1,535	*21.3*	363	*5.0*	8.68
H-PHHL1940 x L-CCSM1927	41	2,668	*65.1*	453	*11.1*	10.25
Total	824	21,447	*26.0*	5,867	*7.1*	8.53

Notes: Variables in italic are shown for the sake of completeness. They are not used in our regressions.