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ABSTRACT

Short- and Long-Run Impacts of Rural Electrification: Evidence from the Historical Rollout of the U.S. Power Grid*

Electrification among American farm households increased from less than 10 percent to nearly 100 percent over a three decade span, 1930{1960. We exploit the historical rollout of the U.S. power grid to study the short- and long-run impacts of rural electrification on local economies. In the short run, rural electrification led to increases in agricultural employment, rural farm population, and rural property values, but there was little impact on the local non-agriculture economy. Benefits exceeded historical costs, even in rural areas with low population density. As for the long run, rural counties that gained early access to electricity experienced increased economic growth that persisted for decades after the country was fully electrified. In remote rural areas, local development was driven by a long-run expansion in the agricultural sector, while in rural counties near metropolitan areas, long-run population growth coincided with increases in housing costs and decreases in agricultural employment. This last result suggests that rural electrification stimulated suburban expansion.

JEL Classification: N72, N92, N32, O13, O18, Q48

Keywords: rural electrification, short run, long run, agriculture, suburbanization

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1 Introduction

Investment in large scale infrastructure is a potentially transformative force for the economy (e.g., Rostow, 1960; Rosenstein-Rodan, 1961; Murphy, Shleifer, and Vishny, 1989). At present approximately a third of international development lending is devoted to major infrastructure projects, and electrification figures prominently among these projects. The focus on electrification is hardly surprising given that 1.2 billion people worldwide still lack access to electricity. Economists have studied the impacts of rural electrification, but evidence has been mixed, in part because electricity offers a range of benefits that are difficult to quantify and poorly measured by standard economic indicators.[1] Moreover, as with many large scale infrastructure projects, evaluations of rural electrification that focus on the short run may fail to capture important long-run effects (Devine Jr., 1983; David, 1990).

This paper studies both short- and long-run economic impacts of rural electrification, exploiting local variation in electricity access during the dramatic expansion in the U.S. power grid from 1930 through 1960. We assess the contemporaneous effects of electricity access on a range of local economic outcomes, and estimate short-run benefits of rural electrification using a new approach that accounts for effects on both productivity and non-market amenities. We use a standard spatial equilibrium model (Rosen 1979; Roback, 1982) as a conceptual framework, which motivates a difference-in-differences empirical approach that evaluates impacts on farmland values, housing prices, and income proxies. We then take advantage of the extended historical time horizon to study long-run impacts of rural electrification on the local economy, using an empirical strategy based on the timing of power grid expansions from 1930 through 2000.

We have an exceptional historical context for studying the effects of rural electrification. In 1930 fewer than 10 percent of American farm households had electricity; 30 years later the electrification of farm households was nearly complete. Importantly, there were large differences in timing of electrification, and these differences were driven in part by plausibly exogenous factors related to costs of extending services. In addition, because urban areas were fully electrified by 1930, we are able to separately identify the effects of rural electrification from potential spillovers from the industrial sector. Historical censuses provide data on a range of outcomes over a 70-year time horizon, allowing us to evaluate both contemporaneous effects and adjustments that

[1] For example, Cowan (1976) famously observed that modern household technologies reduced the drudgery and physical hardship of housework, but did not affect hours worked in the home.

occurred gradually over an extended time period.

The empirical analysis makes use of a panel dataset that combines county outcomes with detailed data on the location and characteristics of large power plants that opened between 1930 and 1960. Our use of county-centroid distances to the nearest power plant gives us an important determinant of rural electrification. Our identification assumption—that rural counties would have evolved similarly absent differences in changes to power plant distance—is supported by three pieces of evidence. First, the historical record indicating that siting decisions were driven primarily by cost considerations and urban electricity demand. Second, the fact that rural consumption accounted for less than 10 percent of electricity generated by these large plants. Third, the fact that baseline rural population characteristics were largely unrelated to subsequent power plant openings.

We have two main results. First, we show that rural electricity access led to a short-run increase in farmland and property values and an expansion in the agricultural sector, but had little impact on local incomes and did not generate spillovers onto nonagricultural sectors. Electricity brought large gains to rural residents, through both improvements in agricultural productivity and non-market housing amenities. We estimate that the average rural household would have paid 24 percent of annual income to gain access to electricity, and that the benefits exceeded the historical costs of extending the grid even at population densities of less than four farms per mile of distribution line. The large gains can be partly attributed to the widespread availability of credit for home modernization during this period, which allowed virtually all American households to take full advantage of this technology.

Second, we find that the timing of rural electrification had long-run effects on economic activity that persisted decades after the country was fully electrified. Early-access counties experienced long-run growth in population and employment, property values, and incomes. By 2000, early-access counties were 15 percent more populous than observationally similar late-electrifying counties. The expansion was not limited to the agricultural sector. Instead, employment growth was concentrated in construction, services, and trade sectors, suggesting that the temporary local advantage of early electrification spurred broad-based local development.

Why did growth in early electrifying rural areas persist decades after the country was fully electrified? This finding is consistent with models in economic geography in which historically sunk advantages continue to coordinate activity to particular locations. We estimate sizable increases in population, employment, and property values in both rural counties located near and far from metropolitan areas that were the result of different forces. In remote rural areas, economic growth appears to have been driven by a persistent expansion in the agricultural sector, which stimulated broader local development through either production complementarities or local co-agglomeration effects (e.g., Hornbeck and Keskin, 2015). In rural counties near metropolitan areas, employment growth was concentrated in non-agricultural sectors, and increases in property values appear to have crowded-out agricultural activity. These effects suggest that rural electrification may have facilitated suburbanization by concentrating population growth in specific rural areas.

Our work makes two primary contributions to the literature. Our first innovation is a new approach to the evaluation of the short-run benefits of electricity access, in which we account for effects on both agricultural productivity and non-market amenities. Because a large fraction of the gains occurred through improved household amenities that might not be captured by standard economic indicators, our results help reconcile the mixed evidence on the effects of rural electrification in the historical and developing country context.[2]

Our second innovation is the evaluation of the long-run impacts of rural electrification using an extended time horizon.[3] We find that early electrification had persistent effects on the spatial distribution of economic activity—a result that is consistent with research on the long-run effects of temporary natural advantages and place-based policies (e.g., Bleakley and Lin, 2012; Kline and Moretti, 2014).[4] Our findings also complement research on the determinants of mid-20th century suburbanization (Baum-Snow, 2007; Boustan, 2010), and support the historical narrative on the impact of rural electrification on suburban growth (e.g., Kline, 1990; Nye, 1993).

The paper proceeds as follows: Section 2 discusses the history of rural electrification; Section 3 introduces a conceptual framework to evaluate the short-run and long-run impacts of rural electrification; Section 4 describes the data; Section 5 presents the empirical strategy; Section 6 presents the results; and Section 7 concludes.

[2]Previous studies find positive effects on agriculture (Kitchens and Fishback, 2015; Chakravorty, Emerick, and Ravago, 2016), local development (Lipscomb, Mobarak, and Barham, 2013; Severnini, 2014), female employment (Dinkelman, 2011; Lewis, 2017), and health (Clay, Lewis, and Severnini, 2016; Lewis, forthcoming), while others show only modest impacts generally (Burlig and Preonas, 2016; Lee, Miguel, and Wolfram, 2016).

[3]We thereby add to research that uses historical settings to identify gradual long-run adjustments (e.g., Davis and Weinstein, 2002; Redding and Sturm, 2008; Hornbeck, 2012).

[4]Electrification was part of the bundle of infrastructure projects provided by the TVA, although Kline and Moretti (2014) focus on agglomeration in the manufacturing sector.

2 Historical Background

2.1 Rural Electrification and Expansions of the Power Grid

Access to electricity in the beginning of the 20th century differed considerably across urban and rural areas. From 1900 to 1930, the fraction of non-farm households with electricity rose from 5 percent to 85 percent. By contrast, fewer than 10 percent of farms were electrified by 1930 (Figure 1). Private electric utilities were initially reluctant to supply electricity to rural areas due to a widely held view of high infrastructure costs per customer. As one publication described,"[a] mile of distribution line can serve 50 to 200 customers in a city; in the country the average is three customers to a mile" (*General Electric Digest*, April 1925).[5]

In the 1930s, the federal government introduced several programs to promote rural electrification. Established in 1933, the Tennessee Valley Authority (TVA) expanded rural access to low cost electricity. The Rural Electrification Administration (REA) was established in 1935, and provided low-interest loans for power line construction in rural areas and to wire farms for electricity.[6] Other major federal projects, such as the Bonneville dam power plant, provided new sources of electricity to rural residents. These programs, combined with the gradual expansion of rural services provided by the private sector, led to a large increase in the proportion of farms with electricity from 1930 to 1955.

The growth in rural electrification coincided with a major expansion in the power grid. In the early 20th century, limitations in transmission technology meant that power plants were typically built near urban areas, with virtually no interconnection across markets. Development was concentrated in the Northeast and in California (Figure 2). Beginning in the 1920s, advances in transmission technology reduced the constraints on where power plants could be sited.[7] New plants were built farther from urban areas (Figure A.1), and were increasingly sited based on efforts to limit costs and to develop an interconnected system that supplied multiple markets.[8] Over the

[5]Several well-publicized studies in the 1920s found that it was unprofitable to extend service to rural customers. For example, the National Electric Light Association supervised the construction of lines to serve 359 families. The experiment lost $8,000 on a $94,000 investment (NELA, 1925).

[6]By 1955, the REA had funded over 1.4 million miles of distribution lines, and was servicing over 4.8 million rural customers (Historical Statistics, 1976, p.829).

[7]Maximum transmission voltages increased from less than 50 kilovolts in 1900 to over 150 kilovolts in the 1920s (Casazza, 2004, p.10).

[8]The interconnected regional system allowed electric utilities to smooth across local peaks in electricity demand and increase overall reliability of services (Hughes, 1993, p.324). Meanwhile, local characteristics were a key determinant of the construction costs and ongoing operating costs of power plants. For example, a 30-megawatt coal-fired plant operating at full capacity burned over 500 tons

next three decades, more than 600 large power plants opened, and the grid expanded throughout the South and Midwest (Figure 2). Although large power plants opened in remote areas, rural demand for electricity was far too small to have influenced siting decisions. In particular, the typical power plant produced roughly 10 times the amount of electricity that could have been consumed by all potential rural customers.[9]

Proximity to power plants was an important determinant of rural electricity access. Electric utilities had an incentive to supply to local customers, since they were responsible for the construction and maintenance of transmission lines, and because power losses are a function of transmission distance. Proximity to the grid was a key determinant of REA loan approval, which hinged on the cooperative's ability to secure low cost wholesale electricity rates (Fishback and Kitchens, 2015). There is a strong empirical relationship between proximity to power plants and the fraction of of farms with electricity (Table A.1).

2.2 Uses of Electricity on the Farm and in the Home

Electricity brought numerous benefits to rural households. Beginning in the 1930s, the federal government enacted several policies that expanded consumer credit for home modernization, allowing virtually all American households to take advantage of this new technology.[10] Electric lighting extended the day and reduced exposure to smoke from kerosene lamps. Labor-saving appliances dramatically reduced the time needed for housework. Washing machines alone saved roughly nine hours per week, and pumped water saved a typical rural household walking a mile a day for water collection (USDA, 1944; Wilson, 1930s).[11]

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of coal per day, and required 200,000 tons of water for coolant each day (Hughes, 1993, p.306). Hydroelectric plants were even more constrained, and needed to be located at a narrow point along a river that had a consistent water flow throughout the year and a sufficient gradient. In a summary of numerous technical reports from the 1920s, Hughes (1993, p.370) argues that a key objective for large power plants was "massing the generating units near economical sources of energy and near cooling water" and "transmitting electricity to load centers" using high voltage transmission lines.

[9] This calculation is based on an average household electricity consumption of 3,854 kWh per year (Historical Statistics, 1976, p.828), and the assumption that each power plant serviced all rural customers within a 60 mile radius (see Table A.1).

[10] In 1934, the federal government established the Electric Home and Farm Authority (EHFA), and the Federal Housing Administration (FHA). The EHFA provided low-cost and long-term financing services to consumers who bought tested and labeled appliances, and purchased electricity from utilities whose rates were approved by the Authority. The FHA also provided home rehabilitation loans under Title I of the National Housing Act, that could be used for electric wiring upgrade, retrofit, and the purchase of modern appliances.

[11] Despite major changes in household technologies, time spent in home production remained roughly constant from 1920 and 1960 (Ramey, 2009). Instead, the time savings was reallocated within the home which led to improvements in child health (Lewis, forthcoming).

Electricity also offered a range of benefits to farm production. By 1960, more than 100 different types of electric farm machines were in use on American farms. Electric milking machines reduced milking time by 50 percent and directly pumped milk into cooled storage tanks, thereby reducing spoilage (Nye, 1990). Electric heaters and lights improved chicken and egg production. Access to pumped water led to large increases in farm irrigation in Western states. In summary, there are many plausible channels through which electrification affected production on the farm and in the home.[12] To illustrate these channels more specifically, we turn to a small scale experiment from the 1920s.

The "Red Wing Project". The Red Wing Project provides an opportunity to examine how electricity was used on the farm. This small scale rural electrification experiment ran from 1923 to 1928 in Minnesota (Stewart, Larson, and Romness, 1927). We collected monthly data on electricity consumption for each household appliance and farm machine.[13]

Electricity consumption was concentrated within the home. Household appliances, lighting, and pumping accounted for 70 percent of farm electricity consumption, while farm machines accounted for the remaining 30 percent (Figure A.2). Household electricity consumption was relatively stable throughout the year, except for seasonality in the use of refrigerators. In contrast, farm consumption varied throughout the year, peaking during the August-September harvest. Nevertheless, total electricity consumption was reasonably stable throughout the year, mitigating the challenges of providing electricity to meet variable loads. Red Wing participants also consumed 50 percent more electricity than had been initially predicted, casting doubt on the long-held view that residential consumption was too low to support broad expansions in rural access.

3 Conceptual Framework

We outline a conceptual framework to guide the interpretation of the local impacts of rural electrification. In the short run, prices respond immediately to changes in electricity access, even though cross-county mobility is limited. In the long run, all factors adjust to the new technology, and worker sorting can have first-order implications for

[12] Nye (1993, p.327) argues that "electrification's usefulness on the farm, as in the factory, was hard to quantify or specify, because so many changes in productivity and efficiency occurred when all the various forms of electrification were combined."

[13] Eight participating farms received electrical services along with free access to a variety of household appliances and electrical farm equipment. Electricity rates charged to Red Wing participants were set to cover overhead and variable costs based on an average of three customers per mile.

welfare.

Short-Run Effects of Rural Electrification. A standard Rosen-Roback spatial equilibrium model (see details in Appendix A.2) is used to evaluate the benefits of rural electrification through its impact on local property values and wages (Rosen, 1979; Roback, 1982).[14] There are a large number of rural counties, each with a fixed supply of land. Tradable agricultural goods are produced using labor and land as inputs.[15] Workers supply labor, and have preferences for a composite consumption commodity, residential land, and housing quality. Workers and producers are fully mobile across counties, and property values and wages are set to clear all markets.

Rural electrification is assumed to affect the local economy through two potential channels: i) increases in agricultural productivity, and ii) improvements in the quality of rural housing. Either effect will make a county more attractive, driving up land and property values.[16] Improvements in agricultural productivity will raise the opportunity cost of land, and wages must rise to compensate workers for the increased cost of housing. Meanwhile, improvements in the quality of rural housing will increase property values and decrease wages to compensate rural producers for the higher input cost of land. In the intermediate case, in which electricity access affects both agricultural productivity and rural housing quality, property values will increase but the wage response is ambiguous and depends on the relative magnitude of the two offsetting effects. The combine effects on property values and wages can thus be used to identify the benefits of rural electrification, and the extent to which the gains were driven by increases in agricultural productivity or improved rural housing. The formal model yields two simple equations based on the reduced-form impacts of rural electrification on land prices and wages that allow us to decompose the benefits to rural residents.

The impact of rural electrification on the local non-agricultural sector is ambiguous. On the one hand, increases in local property values may crowd-out activity in the non-agricultural sector. On the other hand, an expansion in the agricultural production could have positive effects on local industry through either production complementarities or increased demand for local non-tradable goods.

Long-Run Effects of Rural Electrification. Rural counties that gained early access to

[14]Dinkelman and Schulhofer-Wohl (2015) proposes an alternative approach to evaluate the welfare benefits of electricity infrastructure when land markets are not well-defined. In their approach, the welfare bounds are derived based on the income and migration responses.

[15]Because capital is fully mobile, its rate of return will equalize across counties, and capital inputs can be optimized out of the problem.

[16]The relative impacts of rural electrification on land prices and total farmland depends on the supply elasticity of rural land. If the supply of rural land in inelastic, rural electrification can lead to large increases in land prices without having effects on the total land in agriculture.

electricity are predicted to experience a short-run relative expansion in the agricultural sector. It is theoretically ambiguous, however, whether the initial advantage persists in the post-1960 period, once the country was fully electrified.

In spatial equilibrium models that feature local congestion costs, early and late electrifying rural counties should return to their initial population distributions after the technology becomes widely available. This situation is more likely to arise when individuals have homogeneous preferences over neighbors and local amenities, and when there are weak economies of density. The speed of adjustment will depend on the extent to which electrification spurred other local investments, and the time it takes for these investments to fully depreciate.[17] Nevertheless, in the long-run the relative population distribution across rural counties should eventually return to its pre-1930 equilibrium.[18]

Alternatively, the temporary local advantage of early electricity access could have permanent economic effects. There is a growing literature in economic geography demonstrating that temporary local advantages can have persistent effects on the spatial distribution of economic activity (e.g., Bleakley and Lin, 2012; Kline and Moretti, 2014). Early access to electricity may have helped resolve a residential coordination failure across rural areas with similar geographic fundamentals and local characteristics, by concentrating mid-20th century suburban growth into specific locations.[19] Given fixed costs of establishing new suburban communities, these locations could continue to attract residents post-1960. Mid-20th century population mobility led to increased sociodemographic segregation (Boustan, 2010). Preferences to sort into suburban communities on the basis of race and socioeconomic characteristics could reinforce these long-run dynamics (e.g., Behrens, Duranton, Robert-Nicoud, 2014; Behrens and Robert-Nicoud, 2015; Diamond, 2015).

A temporary expansion in agricultural production caused by rural electrification could also foster broad local development through local co-agglomeration forces and productivity spillovers (e.g., Hornbeck and Keskin, 2015). For example, an expansion in the agricultural sector could increase demand for non-traded goods supplied by the local industrial sector. Similarly, increases in local infrastructure investment could

[17]There is some evidence that electrification triggered broader investment within the home. For example, Tobey (1996, p.138-139) argues that "[electrical modernization] led to the whole renovation of the home to bring the quality of living in it up to the electrical standard."

[18]The static model does not account for the long-run trends in rural-urban migration. The predictions are unaffected, however, since all rural counties were similarly affected by these trends.

[19]The expansion in rural electrification occurred during a period of high geographic mobility and rapid suburbanization. In 1950, the fraction of the U.S. population that lived in rural areas and central cities was 36 percent and 30 percent, respectively. By 1990, those fractions were 25 percent and 15 percent.

bring spillover benefits to non-agricultural industries. These long-run effects could occur even in locations that were unsuitable for suburban development.

4 Data

The analysis is based on a balanced panel of 2,162 rural counties from 1930 to 2000.[20] Decadal data on county outcomes are drawn from the Censuses of Agriculture and Population (Haines and ICPSR, 2010; DOC and ICPSR, 2012). The main outcome variables are population (total, rural farm, rural non-farm, and urban); employment (total and sectoral), farm characteristics (farm revenue, number of farms, farmland, and farm size), property values (value of farmland and farm buildings, median dwelling value, and median dwelling rent), and income proxies (retail sales per capita, and payroll per worker in agriculture, manufacturing, and retail sectors).

To construct a measure of electricity access, we rely on a series of seven maps produced by the Federal Power Commission in 1962, which identify the location of all power plants in the U.S., along with various plant characteristics (FPC, 1963). To limit concerns of endogenous power plant siting, we focus on large power plants with at least 30 megawatts of capacity. Using GIS software, we digitize the location of power plants, and link them to historical information on the timing of plant openings from 1930 to 1960. We combine these data with county longitude and latitude to construct a measure of electricity access – county-centroid distance to the nearest power plant. Figure 3 displays the sample counties based on the changes in power plant distance from 1930 to 1960.

5 Empirical Framework

We adopt two complementary empirical approaches to examine the short- and long-run impacts of rural electrification. Both strategies rely on cross-county differences in the timing of electricity access driven by large power plant openings.

To study the short-run effects we adopt a continuous difference-in-differences ap-

[20]The sample is restricted to non-MSA counties located within 200 miles of a power plant in 1930 that had at least 50 percent rural residents in 1930. Excluding counties farther than 200 miles from a power plant limits misspecification due to the fact that changes in distance have little impact on electricity access if a county is too far from a source of generation. From an initial sample of 3,182 counties, we drop 475 non-rural counties, we drop an additional 239 counties that were not located within 200 miles of a power plant in 1930, and we drop an additional 306 counties for which data was missing on one of the main outcomes variables.

proach based on decadal timing of power plant openings for the period 1930 to 1960.[21] We compare changes in outcomes in rural counties that experienced larger increases in electricity access relative to changes in outcomes in rural counties that experienced smaller increases in access that were in the same state and that trended similarly based on pre-1930 characteristics. Formally, we regress outcome variable Y in county c and time t on distance to the nearest large power plant, $DistPP$, county fixed effects, η_c, and state-by-year fixed effects, λ_{st}. The regression models include a vector of baseline socioeconomic conditions in both the rural county, $X_{c,1930}$, and the nearest metropolitan area, $MSA_{c,1930}$, interacted with year fixed effects.[22] These covariates allow for differential trends in outcomes across rural counties according to initial conditions in the county and its nearest metropolitan area. The estimating equation includes an error term, ϵ_{ct}, and is given by

$$Y_{ct} = \beta DistPP_{ct} + \eta_c + \lambda_{st} + \theta_t X_{c,1930} + \theta_t MSA_{c,1930} + \epsilon_{ct}. \quad (1)$$

The variable $DistPP$ is measured in the negative tens of miles, so that the coefficient β represents the effect of a 10 mile decrease in power plant distance.

To study the long-run impacts of rural electrification, we focus on rural counties that experienced large increases in electricity access from 1930 to 1960, and compare changes in outcomes in early electrifying counties relative to late electrifying counties in the post-1960 period.[23] This difference-in-differences approach is based on a comparison across rural counties in the same state that trended similarly according to pre-1930 characteristics. Formally, outcome Y_{ct} is differenced from its value in 1930 and regressed on a county indicator for early access, $EarlyAccess_c$, state-by-year fixed effects, λ_{st}, 1930 county and nearest MSA characteristics, $X_{c,1930}$ and $MSA_{c,1930}$, both interacted with year fixed effects, and an error term, ϵ_{ct}:

$$Y_{ct} - Y_{c,1930} = \beta_t EarlyAccess_c + \lambda_{st} + \theta_t X_{c,1930} + \theta_t MSA_{c,1930} + \epsilon_{ct}. \quad (2)$$

[21]This approach relies on the same identifying assumptions as the discrete treatment difference-in-differences strategy (see Angrist and Pischke, 2009), and has been widely used to evaluate non-discrete treatment effects (e.g., Card, 1992; Acemoglu, Autor, and Lyle, 2004).

[22]County controls, $X_{c,1930}$, include *geographic covariates*: longitude, latitude, and distance to the nearest MSA, *demographic and economic covariates*: total population, fraction white, agricultural employment, manufacturing employment, all measured in 1930. MSA controls, $MSA_{c,1930}$, include total population, fraction white, and manufacturing employment in the nearest MSA in 1930.

[23]We classify counties that had large increases in electricity access as those that experienced above-median decreases in power plant distance from 1930 to 1960. "Early access" counties experienced the majority of the distance reduction reduction from 1930 to 1940 and "late access" counties experienced the majority of the decreases from 1940 to 1960. The qualitative findings are not sensitive to these cutoffs (Table A.2, Panel A).

The effect of early access is allowed to vary by year, and β_t captures the differential change in outcomes between 1930 to year t in early access counties relative to late access counties.[24] Because rural counties were fully electrified by 1960, the coefficient estimates capture whether the short-run impacts of early electricity access were amplified or reversed over time, where $\beta_t > 0$ indicates amplification, $\beta_t < 0$ indicates reversal, and $\beta_t = 0$ indicates constant effects over time. For statistical inference, standard errors are clustered at the county level to adjust for heteroskedasticity and within-county correlation over time.[25]

The identifying assumption for the empirical analysis is that outcomes in rural counties in the same state would have trended similarly in the absence of changes in electricity access.[26] This assumption is supported by three main pieces of evidence. First, the historical narrative that the siting decisions of large power plants were made primarily on the basis of local geographic and topological conditions that influenced construction and operating costs, and a desire to develop an interconnected power grid across multiple urban areas, rather than a desire to serve sparsely population rural areas (Hughes, 1993; Casazza, 2004).[27]

Second, rural electricity demand accounted for only a small fraction of the total electricity produced by large power plants. In particular, rural customers accounted for less than 10 percent of total electricity produced by the typical power plant in the sample. Thus, it is highly unlikely that these large power plants would have been built in response to changes in rural demand for electricity.

Third, neither the timing nor the magnitude of changes in county distance to power plants between 1930 and 1960 were related to the baseline demographic and economic conditions in rural counties. Table 1 reports mean county characteristics in 1930 (column 1) and the logarithm of within-state differences in baseline characteristics for rural counties that experienced above-median relative to below-median decreases in distance to power plants from 1930 to 1960. We report these estimated differences separately for

[24] For this class of regression, in which the sample is balanced and the regressors are fully interacted with each time period, differencing the data and including county fixed effects yield numerically identical coefficients (as in the case of two time periods). Differencing is more efficient when the untransformed error term is closer to a random walk, the differenced coefficients are easier to interpret, and differencing is computationally faster (see Hornbeck, 2012).

[25] Conley (1999) standard errors that allow for spatial correlation in outcomes across counties are similar to the county-level standard errors. Relative to county-clustered standard errors, the increase in Conley standard errors ranged from -4 to 23 percent for a 100-mile cutoff.

[26] In practice, this assumption must hold only after controlling for differential trends based on geography, and baseline demographic and economic conditions.

[27] Morton (2000, p.29) notes that "private utilities insisted that extending service to these rural customers would be unprofitable." Moreover, given the costs of transmission line construction, it was far cheaper to extend rural lines to build new plants to meet rural demand (Beall, 1940).

rural counties that gained early access (column 2) and late access (column 3). Future increases in electricity access were generally unrelated to baseline farm outcomes (Panel A). Estimates for agricultural employment, farm population, and number of farms are small and statistically insignificant. Counties that experienced large decreases in distance tended to have slightly larger farms, consistent with expansion of the power grid into less densely populated areas. Panel B reports baseline differences in rural population and employment characteristics. There were few systematic differences across the different groups of rural counties. If anything, counties that experienced increases in electricity access tended to be less populous, had less manufacturing employment, and had a higher fraction of non-white residents. Column 4 reports the difference in the estimates across early access (column 2) and late access (column 3) rural counties. There were no significant differences in the baseline characteristics according to the *timing* of rural electricity access. Importantly, the fixed-effects specification controls for any baseline differences across rural counties, and the controls $\theta_t X_{c,1930}$ and $\theta_t MSA_{c,1930}$ allow rural counties to trend differentially according to observable baseline conditions.

6 Results

6.1 Short-Run Effects of Rural Electrification

6.1.1 Population, Employment, and Farm Output

Table 2 (col. 2 to 5) reports coefficient estimates of $DistPP$ from equation (1) across several different specifications. Column (2) includes county and year fixed effects a linear state trend, and geographic covariates interacted with year; in column (3) we add controls for baseline demographic and economic covariates interacted with year to allow for differential trends based on initial county characteristics; in column (4) we add controls for differential trends based on conditions in the nearest metropolitan area; and in column (5) we replace the state trend with state-year fixed effects, so that the results rely solely on within-state variation in electricity access.

Access to electricity is associated with relative increases in farm population and agricultural employment (Panel A). Given the national trend in rural-urban migration from 1930 to 1960, the coefficient estimates imply that the expansion in rural electricity access slowed to pace of rural depopulation from 1930 to 1960. Rural electrification also led to an expansion in agricultural output as measured by farm revenue (Panel B). The expansion in farm output was driven both by a response on the extensive margin, through increases in the number of farms and total land in agriculture, and a response on the intensive margin, through increases in farm size. There is also some evidence that electricity and tractors were complements in agricultural production. These findings are consistent with evidence on the effects of the REA on farm output in the 1930s (Fishback and Kitchens, 2015), and the role of the tractor in mid-20th century American agricultural development (Olmstead and Rhode, 2001; Steckel and White, 2012).

Rural electrification could generate either positive or negative employment spillovers. An expansion in the agricultural sector could spur broad local development through productivity spillovers and increased demand for locally-traded goods, or it could crowd-out non-agricultural production. To explore this question, we examine the broader effects of rural electricity access on the local economy. Table 3 (Panel A) shows virtually no impact on total population or employment. The increase in agricultural employment was roughly offset by a decline in manufacturing employment and there were no significant changes in other sectors (Panel B). Changes in rural electricity access also do not appear to have affected the composition of the local population. Coefficient estimates on the fraction white, the fraction of adults with a high school diploma, and retail sales per capita are all small and statistically insignificant. Together these results suggest that, in the short-run, rural electrification slowed the pace of the rural-urban transition within counties, but had little impact on population flows across counties.

6.1.2 Property Values, Income, and Rural Welfare

Table 4 reports the estimated impacts of electricity access on property values and income proxies. Rural electrification led to increases in local property values. The coefficient estimates for farm values, median dwelling values, and median dwelling rents are all positive and statistically significant. In contrast, rural electrification had no significant impact on local incomes, as measured by farm, retail, and manufacturing payroll per worker. Together, these findings are consistent with the intermediate scenario in the Rosen-Roback framework, in which electricity brought benefits through both increases in agricultural productivity and improvements in rural housing quality.

The reduced-form estimates can be applied to calculate the aggregate benefit of electricity to the rural sector (see Appendix A.2, for details). The annual willingness-to-pay for a change in electricity access, de, is given by the sum of the willingness-to-pay for the non-market amenity, p_e^*, across all rural workers, N^R, and the decrease in the unit production costs, C_e, across all agricultural goods produced in the county, X^R

according to the following expression:

$$p_e^* N^R + \big[- C_e X^R \big] = \frac{d\ \log q}{de} \cdot L^R \cdot q,$$

where q denotes the annual value per acre of farmland, L^R denotes the total acres in farming, and $\frac{d\ \log q}{de}$ denotes the impact of a change in electricity access on the logarithm of farmland value. We combine the estimated impact of electricity access on farmland value (Table 4, col. 5) with farmland acreage per county, $L^R = 306,245$, and the annual value per acre, $q = \$11.35$, to calculate the rural willingness-to-pay for electricity.[28] The estimates imply that the annual willingness-to-pay was $4.6 million per rural county or $2,400 per farm.[29] These estimates imply that the typical farm would have forgone 24 percent of annual income to gain access to electricity.

The reduced-form estimates for land values and income can also be combined to evaluate the extent to which the benefits of electrification were driven by increases in agricultural productivity or improvements in rural housing quality. In particular, the sum of the benefits to rural workers is given by

$$p_e^* N^R = \left(k_l \cdot \frac{d \log q}{de} - \frac{d \log w}{de} \right) \cdot w \cdot N^R,$$

where $k_l = 0.18$ denotes the fraction of the household's annual budget spent on residential land, and $w = \$4,393$ denotes the annual income of a rural worker (see Appendix A.2).[30] We calculate that 60 percent of the gains from rural electrification were due to the non-market amenities associated with improved rural housing.[31]

Despite the large estimated benefits of rural electrification, fewer than four percent of farms owned generators in 1930, probably because of their high cost. The purchase price of a standard 1-kilowatt diesel generator ranged from $2,300 to $5,200, and operating costs typically exceeded $500 per year (Nye, 1990, p.295). In contrast, the historical cost of extending the grid ranged from $13,500 to $16,000 per mile in the early 1930s, and quickly fell to below $7,200 under the REA (Beall, 1940). Even at population densities of less than four farms per mile, line extensions were justified

[28] We rescale the estimates by the relationship between distance on the fraction of farms with electricity, $\frac{de}{dDistPP} = 0.0034$ (Table A.1, col. 2), and use a four percent mortgage interest rate to annualize agricultural land values (see Saulnier, Halcrow, and Jacoby, 1958; Hornbeck, 2012).

[29] The benefits per county are given by $\frac{d\ \log q}{de} \cdot L^R \cdot q = \big([0.0045/0.0034] \times 11.35 \times 306,245\big) = \$4.6$ million (1990 USD).

[30] The residential budget share is calculated as the fraction of income spent on rent in 1950. Rural incomes are calculated assuming a 0.6 labor share in agriculture (Herrendorf and Valentinyi, 2008).

[31] The annual non-market benefits from rural electrification are $p_e^* N^R = \big(0.18 \times [0.0045/0.0034] \times 4,393 \times 2,606\big) = \$2.8$ million per county or $1,000 per agricultural worker.

based on the value to rural residents.

6.1.3 Sensitivity Analysis

In Table 5, we examine the robustness of the main estimates to several alternative specifications and samples. Column (1) reports the baseline estimates. In column (2), we add additional controls for baseline rural infrastructure (the fraction of farms with electricity and the fraction of farms with access to a hard surface road in 1930) interacted with year fixed effects. In practice, allowing for differential trends according to baseline rural infrastructure has little impact on the main results.

Next, we explore the sensitivity of the results to alternative samples. In column (3), we exclude counties located within 30 miles of a power plant to further address concerns that power plants were built in response to changes in local demand for electricity. In column (4) we exclude counties west of the 100th meridian, which were generally larger, and where, as a result, county-centroid distance might be a noisier measure of electricity access. In column (5) we exclude counties in which more than 25 percent of farms were electrified by 1930, where there was less scope to expand rural access. In column (6) we exclude counties serviced by the TVA, which provided a range of local infrastructure investments that may have influenced rural outcomes independently of electrification (Kline and Moretti, 2014). None of these sample restrictions affects the main qualitative results.

In the final two columns, we further explore the question of endogenous power plants siting. We re-estimate the baseline model using only very large power plants – those with at least 50 MW of capacity – that were almost certainly not built in response to changes in rural electricity demand. We also re-estimate the regressions using only power plants operated by private utilities, that were generally uninterested in servicing high cost rural customers. The main findings are broadly similar in both models.

6.2 Long-Run Effects of Rural Electrification

6.2.1 Early Electricity Access and Long-run Outcomes

To motivate our empirical strategy for the long-run analysis, and to assess the validity of the common trends assumption, Figure 4 plots the estimated βs from equation (2). These coefficients capture the change in outcomes in early electricity access counties relative to late electricity access counties in each census year for the period 1910 to 2000.[32] Panel A graphs the estimates for population and employment, Panel B graphs

[32] Changes are estimated relative to the 1930 baseline year.

the effects for property values and income, and Panel C graphs the estimates for rural outcomes.

Early and late electricity access counties trended similarly in the pre-1930 period. The coefficient estimates are small and generally insignificant prior to 1930, thereby providing support for the identifying assumption that the two groups would have trended similarly in the post-1960 period if not for differences in the timing of electrification. Despite these initial similarities, early and late access counties experienced markedly different outcomes in the post-1960 period. Early electricity access counties experienced large and persistent growth in population and employment from 1960 to 2000. Over time, they also experienced substantial relative increases in property values and modest increases in worker incomes. The relative expansion was not driven by the rural sector. Rural population, agricultural employment, and farmland decreased in early access counties.

Table 6 reports the coefficient estimates from equation (2) for a range of outcomes. Early access counties experienced relative population and employment growth in each decade from 1960 to 2000 (Panel A). By 2000, early access counties were 15 percent more populous and had 18 percent higher employment than late access counties. Employment growth was concentrated in non-agricultural sectors. By 2000, relative employment in retail and construction had increased by more than 22 percent in early access counties. The estimates for manufacturing employment are generally insignificant and smaller in magnitude, suggesting that the positive employment spillovers were concentrated in sectors that produced locally-traded goods.

Early electrifying counties experienced long-run increases in property values (Panel B). Although property values were similar in 1960, significant differences between early and late access counties emerged over the subsequent decades, and by 1990, housing and land values were 10 to 12 percent higher in early access counties. Early access to electricity also led to persistent relative increases in retail payroll per worker and manufacturing payroll per worker.[33] Together, the results in Panels A and B show that early access to electricity was a catalyst for broad-based local development.

Despite long-run growth in total population and property values, the positive effects of electrification on the agricultural sector were temporary (Panel C). Early access counties experienced a significant decrease in agricultural employment in 1960, and persistent declines in farmland in the post-1960 period. Farm revenue per worker

[33] Given the possibility of long-run worker sorting (Table 8), the homogeneity assumption underlying the standard Rosen-Roback framework is unlikely to hold, so the relative impacts on property values and incomes cannot be directly compared to estimate the long-run welfare benefits associated with early electrification.

rose significantly from 1960 to 1980, which could be a result of either slow-moving investments or the dissolution of lower productivity farms.[34]

6.2.2 Early Electricity Access and Patterns of Rural Development

The timing of rural electrification led to divergent outcomes that persisted decades after the country was fully electrified. These findings are consistent with research in economic geography showing that a temporary local advantage can permanently alter the spatial distribution of economic activity, particularly when there increasing returns to density, fixed costs to relocation, or diverse preference preferences over community characteristics (e.g., Bleakley and Lin, 2012; Kline and Moretti, 2014; Severnini, 2014). In these settings, historically sunk investments can serve as a coordination mechanism for subsequent investments and can continue to draw individuals and resources to particular locations.

The mid-20th century was a period of high population mobility and residential sorting (Baum-Snow, 2007; Boustan, 2010). Several historians have argued that rural electrification contributed to suburbanization. For example, Nye (1993, p.327) claims that "because of electricity, for the first time rural domestic working conditions were roughly similar to those in the city. This new equivalence encouraged urban deconcentration, and Americans moved farther and farther away from the city as rural areas were electrified." If there were large fixed costs of establishing new suburban communities, these areas may have continued to attract residents in the post-1960 period. Alternatively, rural electrification may also have fostered long-run development in remote rural areas through local economic spillovers from the agricultural sector. These local benefits might have included productivity spillovers, shared infrastructure, or increased demand for locally-traded goods (Hornbeck and Keskin, 2015).

To explore the mechanisms through which rural electrification affected long-run local development, we estimate a generalized version of equation (2) in which the impact of early electricity access is interacted with indicators for counties below- or above-median distance to a metropolitan area in 1930. These models allow us to examine whether there were differential long-run effects depending on whether a rural

[34] The findings in Table 6 are robust to several alternative specifications. In Table A.2, Panel A, we redefine late access rural counties as those that experienced the majority of the reduction in distance between 1950 and 1960. The key results are largely unchanged. In Panel B, we report the estimates from a triple-difference strategy, base on the full sample of 2,162 rural counties, in which early electricity access is interacted with an indicator for counties that experienced above-median decreases in distance between 1930 and 1960. Again, the results are qualitatively similar.

county was a suitable candidate for suburban expansion.[35]

Early electricity access had similar effects on long-run population and employment growth in counties located near and far from a metropolitan area (Table 7, cols. 1 and 2), and estimated impacts on property values and local incomes were generally positive in both areas (Table 7, cols. 3 to 5; Table 8, cols. 1 to 3). Nevertheless, the forces behind the relative expansions appear to have been different. In remote rural areas, local development appears to have been fuelled by the agricultural sector. Early access led to long-run relative increases in farm productivity and farm population. By 2000, farm revenue per worker was 15 percent higher and the rural farm population had increased by 17 percent. This expansion in agriculture coincided with broader local development. Early access is associated with increases in housing construction and employment growth in retail and sales sectors, but did not affect the sociodemographic composition of the local population (Table 8, col. 4 to 8). These results are consistent with local spillover effects through either a long-run increase in the demand for local non-traded goods or cross-sector productivity complementarities.

Early electricity access led to substantial increases in population in rural counties near metropolitan areas. Unlike remote counties, however, the expansion coincided decreases in rural farm population and farmland. One explanation for these findings is that mid-20th century suburban growth crowded-out activity in the agricultural sector. Consistent with this view are the large relative increases in housing prices and land values which raised the opportunity cost of agricultural production. Over time, early access counties also became increasingly white and had higher levels of education (Table 8, cols. 4 and 5), changes that coincide with the demographic characteristics of the rising suburban population (Boustan, 2010) and that support the view that the incentive to co-locate on the basis of race and education reinforced the long-run population dynamics.[36]

7 Conclusion

The expansion of the power grid from 1930 to 1960 brought electricity to millions of rural households. In the short-run, rural electrification led to an expansion in the

[35] Given limited within-state variation to separately identify the parameters of the generalized model, we omit trends based on MSA proximity in this specification. Qualitatively similar, although less precise estimates, are found when these controls are included.

[36] In Table A.3, we show that these main findings are robust to controls for the interstate highway system (Baum-Snow, 2007). We find that both transportation and electricity infrastructure had independent long-run effects on population growth in rural areas.

agricultural sector and slowed the pace of rural depopulation, but had little impact on non-agricultural sectors. Electricity brought large gains to rural residents through both increases in agricultural productivity and improvements in rural housing, that exceeded the historical costs of extending the grid even at low population densities.

The historical expansion in rural electricity access was complemented by federal policies providing household credit, which together brought large benefits to rural residents. Federal programs such as FHA and EHFA provided widespread access to credit to retrofit homes and to purchase electrical appliances, allowing virtually all households to take advantage of the new technology. In less developed countries, where the benefits of rural electrification have been found to be much smaller (e.g., Burlig and Preonas, 2016; Lee et al., 2016), one issue may be limited access to credit. Additional empirical research is needed to quantify the extent to which credit constraints might offset the benefits of rural electrification in the developing world.

In the long run, rural areas that gained early access to electricity experienced economic growth that persisted decades after the country was fully electrified. The relative expansion was not limited to the agricultural sector. Instead, rural electrification spurred broad-based local development. One important channel appears to have occurred through suburbanization: by helping to coordinate population and investment flows into particular areas, rural electrification appears to have fostered long-run suburban development.

These long-run findings may also have relevance for policy in developing countries. The rural-urban transition has long been considered a central force for economic development (Schultz, 1953; Caselli, 2005; Restuccia, Yang, and Zhu, 2008). Despite recent efforts to facilitate this process, there are concern about the costs of large-scale migration of rural workers and the strains that this transition could place on existing city infrastructure (e.g., World Bank, 2012; Man, 2013). The historical U.S. experience highlights how targeted investments in rural electrification infrastructure can foster long-run local development without relocating large numbers of workers.

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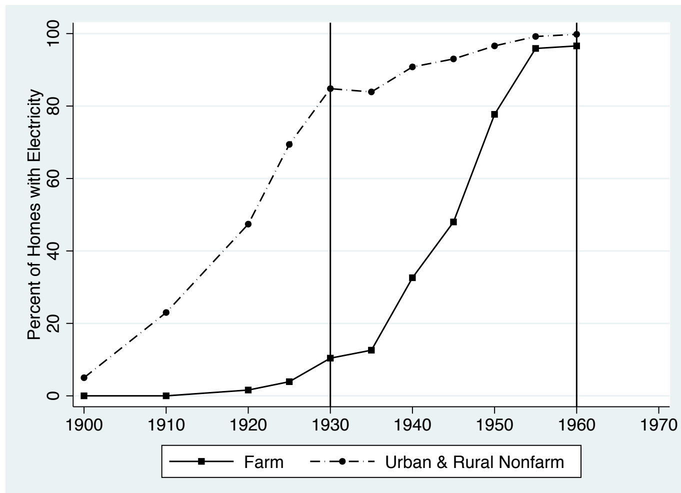
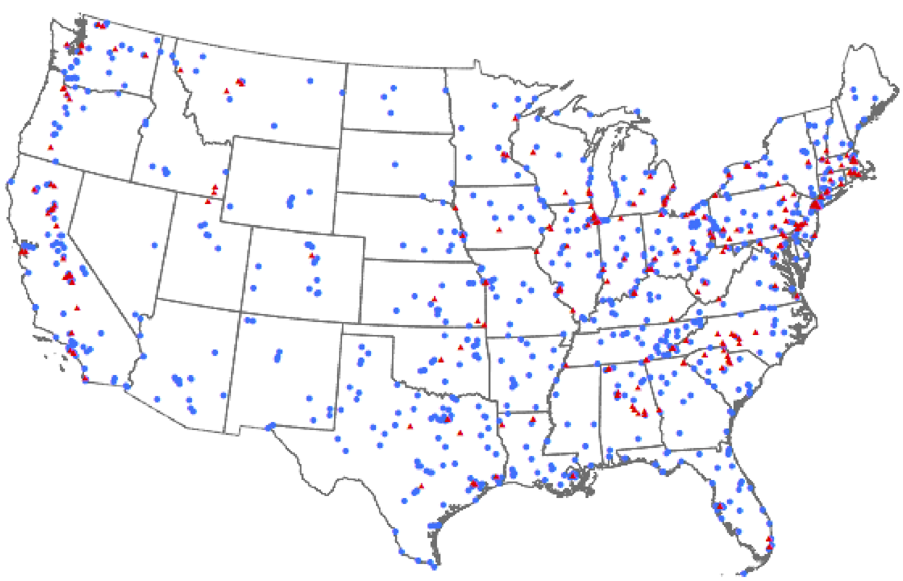
8 Figures and Tables

Figure 1: % farm and nonfarm households with electricity



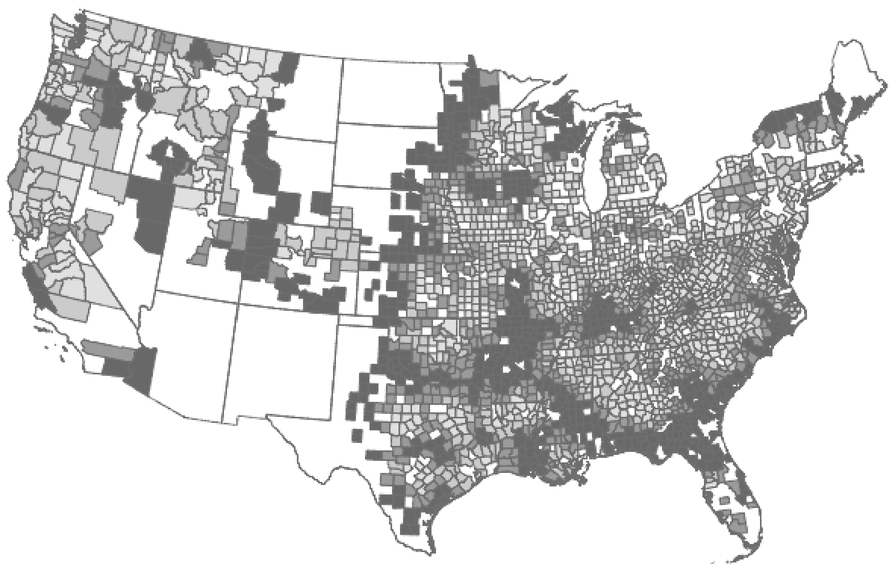
Source: Lebergott (1976, p.280), Historical Statistics of the United States, 1976, p.827).

Figure 2: Large Power Plant Openings, 1930-1960



Note: The figure reports the location of large power plants (>30MW of nameplate capacity). Red triangles identify power plants in operation in 1930. Blue circle identify power plants that opened between 1930 and 1960. Source: Federal Power Commission (1963).

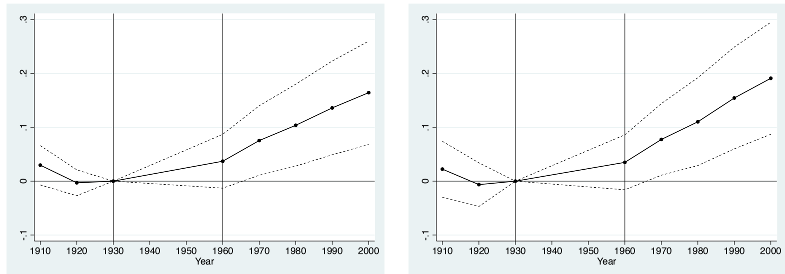
Figure 3: Sample counties and power plant openings



Notes: The figure presents the 2,162 counties in the sample. Counties are shaded by quartile of change in power plant distance between 1930 and 1960, with darker shades indicating larger decreases in distance.

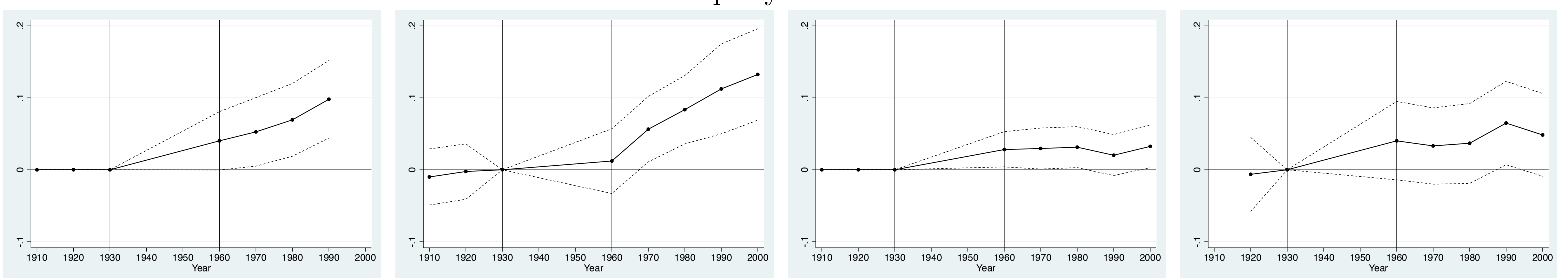
Figure 4: Estimated differences in log outcomes between early electricity access and late electricity access rural counties

Panel A: Population and Employment



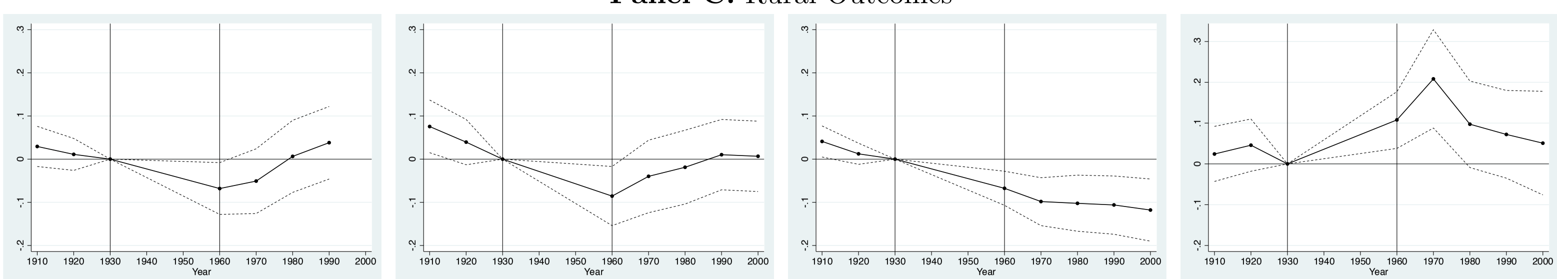
Population Employment

Panel B: Property Values and Income



Median Dwelling Value Farmland Value Retail Payroll per Worker Manuf. Payroll Per Worker

Panel C: Rural Outcomes



Rural Population Agricultural Employment Farmland Farm Revenue per Worker

Notes: Each figure graphs the estimated coefficients (β) from equation (2). The solid line denotes the difference in log outcomes between early electricity access and late electricity access rural counties. The dashed lines denote the 95% confidence interval.

Table 1: County means in 1930, by changes in electricity access 1930-1960

		Log differences in outcomes: Above median vs. below median Δ in p.p. distance, 1930-1960		
	Sample mean (1)	Early Access (2)	Late Acess (3)	Difference (2)-(3) (4)
Panel A. Farm Outcomes				
Agriculture Employment	3,574	-0.017	0.021	-0.038
Rural Farm Population	11,022	0.001	0.010	-0.008
Number of farms	2,283	-0.023	-0.002	-0.021
Farmland, per 100 county acres	66.74	0.047*	0.018	0.030
Farm Size	180.76	0.091**	0.082**	0.009
Panel B. Population and Employment				
Total Population	22,485	-0.054	-0.041	-0.013
Rural Non-Farm	6,882	-0.038	-0.102**	0.064
Urban	4,582	-0.057	-0.095	0.038
White	19,024	-0.027	-0.069*	0.042
Total Employment	7,832	-0.083**	-0.039	-0.044
% Manufacturing	10.12	0.006	-0.092*	0.099
% Retail	8.35	-0.021	0.013	-0.035
% Construction	4.39	-0.063	-0.010	-0.053
N(counties)	2,162			

Notes: Column 1 reports average values for the 2,162 sample counties in 1930. Columns (2) and (3) report coefficients from a single regression of the county characteristic on dummy variables for counties with above-median decreases in power plant distance between 1930 and 1960. We allow this effect to vary according to whether the majority of the decrease occurred early (1930-1940) or late (1940-1960). Column (4) reports the difference between the coefficient estimates in columns (2) and (3). **,*, + denote significance at the 1%, 5%, and 10% level, respectively.

Table 2: The effect of electricity access on rural outcomes

	Mean Dep. Var.	Coefficient on *DistPP*: Effect of a 10 mile decrease in p.p. distance			
	(1)	(2)	(3)	(4)	(5)
Dependent Variables					
A. Population and Employment					
Rural Farm Pop.	8,488	68.63**	36.77**	38.47**	30.53*
		(21.73)	(11.30)	(11.37)	(12.12)
Agr. Employment	2,606	34.18**	23.44**	24.79**	24.75**
		(6.42)	(3.84)	(4.14)	(4.46)
B. Agricultural Output					
Log Farm Revenue	9.43	0.0070*	0.0060*	0.0064*	0.0074*
		(0.0029)	(0.0029)	(0.0029)	(0.0030)
Number of Farms	1,937	12.92**	9.56**	9.36**	8.98**
		(3.55)	(2.26)	(2.25)	(2.36)
Farmland	306,245	889.79	953.20	1,430.82*	1,579.66*
		(584.67)	(589.60)	(652.18)	(720.07)
Farm Size	252	5.08	4.39	5.20+	5.47
		(3.12)	(3.08)	(3.14)	(3.48)
Tractors per Farm	0.59	0.0052**	0.0054**	0.0060**	0.0068**
		(0.0018)	(0.0018)	(0.0018)	(0.0019)
County & Year FE + State trend		Y	Y	Y	Y
Geographic Covariates		Y	Y	Y	Y
Demog and Econ Covariates			Y	Y	Y
Near MSA Covariates				Y	Y
State-Year FE					Y
	N(Obervations) = 8,648		N(Counties)= 2,162		

Notes: All regressions include controls for county and year fixed effects. Each cell reports the point estimate from a different regression. Geographic covariates are county longitude, latitude, and proximity to the nearest MSA interacted with year fixed effects. Demographic and economic controls include total population, fraction white, employment in manufacturing, and employment in agriculture, all measured in 1930 and interacted with year fixed effects. Near MSA covariates include total population, fraction white, and manufacturing employment in the nearest MSA in 1930 interacted with year fixed effects. Standard errors are clustered at the county-level. **,*, + denote significance at the 1%, 5%, and 10% level, respectively.

Table 3: The effect of electricity access on other local outcomes

	Mean Dep. Var.	Coefficient on *DistPP*: Effect of a 10 mile decrease in p.p. distance			
	(1)	(2)	(3)	(4)	(5)
Dependent Variables					
A. Population					
Rural Farm	8,488	68.63**	36.77**	38.47**	30.53*
		(21.73)	(11.30)	(11.37)	(12.12)
Rural Non-Farm	9,335	-33.71	5.47	8.91	2.49
		(30.04)	(27.36)	(27.99)	(30.09)
Urban Population	7,345	-116.23+	41.36	71.06	80.34
		(61.70)	(52.80)	(55.26)	(61.73)
Total	25,168	-81.30	83.60	118.44+	113.36
		(69.91)	(65.44)	(69.61)	(76.11)
B. Employment					
Agriculture	2,606	34.18**	23.44**	24.79**	24.75**
		(6.42)	(3.84)	(4.14)	(4.46)
Manufacturing	1,526	-41.58**	-17.80**	-16.46**	-16.98*
		(7.75)	(6.33)	(6.33)	(6.87)
Retail	1,138	-12.69*	3.22	4.66	5.40
		(5.31)	(4.39)	(4.59)	(5.05)
Construction	464	-4.06	0.60	1.21	1.78
		(2.52)	(2.39)	(2.52)	(2.67)
Total	8,439	-26.18	30.40	39.21	39.58
		(28.18)	(26.63)	(27.74)	(28.46)
C. Sorting and Amenities					
% White	86.9	-0.0501	-0.0630	-0.0501	-0.0341
		(0.0723)	(0.0711)	(0.0719)	(0.0790)
% of 25+ with High School	26.2	0.2236	0.2469	0.2629	0.4727
		(0.3459)	(0.3693)	(0.3874)	(0.5934)
Log Retail Sales per Capita	0.86	0.0002	-0.0002	-0.0006	0.0009
		(0.0017)	(0.0016)	(0.0016)	(0.0016)
County & Year FE + State trend		Y	Y	Y	Y
Geographic Covariates		Y	Y	Y	Y
Demog and Econ Covariates			Y	Y	Y
Near MSA Covariates				Y	Y
State-Year FE					Y
	N(Obervations) = 8,648		N(Counties)= 2,162		

Notes: All regressions include controls for county and year fixed effects. Each cell reports the point estimate from a different regression. Geographic covariates are county longitude, latitude, and proximity to the nearest MSA interacted with year fixed effects. Demographic and economic controls include total population, fraction white, employment in manufacturing, and employment in agriculture, all measured in 1930 and interacted with year fixed effects. Near MSA covariates include total population, fraction white, and manufacturing employment in the nearest MSA in 1930 interacted with year fixed effects. Standard errors are clustered at the county-level. **,*, + denote significance at the 1%, 5%, and 10% level, respectively.

Table 4: The effect of electricity access on property values and income proxies

	Mean Dep. Var.	Coefficient on *DistPP*: Effect of a 10 mile decrease in p.p. distance			
	(1)	(2)	(3)	(4)	(5)
Dependent Variables					
A. Property Values					
Log Value of Farmland	5.41	0.0060**	0.0057**	0.0051**	0.0045*
and Farm Buildings		(0.0019)	(0.0020)	(0.0019)	(0.0019)
Log Median Dwelling Value	9.87	0.0061**	0.0050**	0.0048**	0.0052**
(Owner-Occupied)		(0.0018)	(0.0017)	(0.0017)	(0.0017)
Log Median Dwelling Rent	4.83	0.0049**	0.0039**	0.0038**	0.0037**
(Renter-Occupied)		(0.0013)	(0.0013)	(0.0013)	(0.0013)
B. Income Proxies					
Log Farm Revenue	1.86	-0.0034	-0.0043+	-0.0040	-0.0017
Per Worker		(0.0026)	(0.0026)	(0.0026)	(0.0026)
Log Retail Payroll	2.24	0.0015	0.0012	0.0010	0.0015
Per Worker		(0.0010)	(0.0009)	(0.0010)	(0.0010)
Log Manufacturing Payroll	2.31	0.0012	0.0016	0.0011	0.0019
Per Worker (Obs=7,465)		(0.0022)	(0.0022)	(0.0023)	(0.0024)
County & Year FE + State trend		Y	Y	Y	Y
Geographic Covariates		Y	Y	Y	Y
Demog and Econ Covariates			Y	Y	Y
Near MSA Covariates				Y	Y
State-Year FE					Y
	N(Obervations) = 8,648		N(Counties)= 2,162		

Notes: All regressions include controls for county and year fixed effects. Each cell reports the point estimate from a different regression. Geographic covariates are county longitude, latitude, and proximity to the nearest MSA interacted with year fixed effects. Demographic and economic controls include total population, fraction white, employment in manufacturing, and employment in agriculture, all measured in 1930 and interacted with year fixed effects. Near MSA covariates include total population, fraction white, and manufacturing employment in the nearest MSA in 1930 interacted with year fixed effects. Standard errors are clustered at the county-level. **,*, + denote significance at the 1%, 5%, and 10% level, respectively.

Table 5: Robustness tests

	Coefficient on *DistPP*: Effect of a 10 mile decrease in p.p. distance							
			Alternate samples				Restrict power plants	
	Baseline estimates (1)	Add controls for 1930 infrastructure (2)	Drop counties <30 miles from a power plant (3)	Drop counties west of 100th meridian (4)	Drop counties with high elect. access in 1930 (5)	Drop TVA counties (6)	Use only power plants $\geq$ 50 MW (7)	Use only private power plants (8)
A. Population and Employment								
Agr. Employment	24.7491**	26.2713**	17.4518**	18.8692**	19.9432**	28.9017**	17.6925**	13.0044*
	(4.4615)	(4.3891)	(5.3110)	(3.9881)	(4.4267)	(4.5991)	(4.7510)	(5.2420)
Rural Farm Population	30.5314*	35.5064**	19.6281	13.7254	26.2148*	42.3792**	17.6012	21.5763
	(12.1221)	(12.0772)	(13.4740)	(14.2523)	(12.4749)	(12.4209)	(11.7905)	(14.8845)
B. Farm Output								
Log Farm Revenue	0.0074*	0.0083**	0.0110**	0.0018	0.0078*	0.0100**	0.0015	0.0005
	(0.0030)	(0.0030)	(0.0041)	(0.0030)	(0.0031)	(0.0031)	(0.0026)	(0.0038)
Number of Farms	8.9851**	10.0251**	4.5053	8.8366**	8.3096**	12.7309**	7.4248**	6.5464*
	(2.3578)	(2.3269)	(2.9155)	(2.7012)	(2.4787)	(2.4305)	(2.4575)	(3.1728)
Farmland	1,579.66*	1,587.40*	2,015.52+	77.75	1,117.35+	1,680.75*	1,030.53	-92.64
	(720.08)	(721.03)	(1,052.78)	(440.69)	(622.92)	(728.18)	(665.66)	(708.70)
Farm size	5.4671	4.7597	14.0085*	1.4807	3.0857	6.1750	2.5624	-3.0833
	(3.4807)	(3.4631)	(5.8620)	(3.6285)	(3.8515)	(3.8278)	(2.1269)	(3.4563)
C. Property Values								
Log Value of Farmland	0.0045*	0.0043*	0.0046+	0.0065**	0.0047*	0.0051*	0.0031*	0.0087**
and Farm Buildings	(0.0019)	(0.0020)	(0.0027)	(0.0021)	(0.0020)	(0.0021)	(0.0015)	(0.0023)
Log Median Dwelling Value	0.0052**	0.0047**	0.0049*	0.0080**	0.0058**	0.0047**	0.0053**	0.0095**
(Owner-Occupied)	(0.0017)	(0.0017)	(0.0022)	(0.0019)	(0.0018)	(0.0018)	(0.0016)	(0.0022)
Log Median Dwelling Rent	0.0037**	0.0032*	0.0020	0.0056**	0.0038**	0.0041**	0.0035**	0.0055**
(Renter-Occupied)	(0.0013)	(0.0013)	(0.0017)	(0.0015)	(0.0014)	(0.0014)	(0.0012)	(0.0018)
D. Income Proxies								
Log Farm Revenue	-0.0017	-0.0020	0.0040	-0.0059*	-0.0014	-0.0003	-0.0069**	-0.0057+
Per Worker	(0.0026)	(0.0026)	(0.0036)	(0.0028)	(0.0027)	(0.0028)	(0.0021)	(0.0033)
Log Retail Payroll	0.0015	0.0014	0.0002	0.0031**	0.0014	0.0009	0.0020*	-0.0003
Per Worker	(0.0010)	(0.0010)	(0.0013)	(0.0011)	(0.0010)	(0.0010)	(0.0009)	(0.0013)
Log Manuf. Payroll	0.0019	0.0020	-0.0001	0.0039+	0.0029	0.0022	0.0035+	0.0044+
Per Worker	(0.0024)	(0.0024)	(0.0036)	(0.0022)	(0.0025)	(0.0025)	(0.0019)	(0.0025)
Full controls	Y	Y	Y	Y	Y	Y	Y	Y

Notes: All regressions include controls for county and year fixed effects. Each cell reports the point estimate from a different regression. Geographic covariates are county longitude, latitude, and proximity to the nearest MSA interacted with year fixed effects. Demographic and economic controls include total population, fraction white, employment in manufacturing, and employment in agriculture, all measured in 1930 and interacted with year fixed effects. Near MSA covariates include total population, fraction white, and manufacturing employment in the nearest MSA in 1930 interacted with year fixed effects. Standard errors are clustered at the county-level. **,*, + denote significance at the 1%, 5%, and 10% level, respectively.

Table 6: Long-run effects of early electricity access

Panel A: *Population and Employment Outcomes*

	Overall		Sectoral			
	Log Population	Log Employment	Log Emp. in Agr.	Log Emp. in Mfg.	Log Emp. in Retail	Log Emp. in Construction
	(1)	(2)	(3)	(4)	(5)	(6)
Early Access ×						
1960	0.0347	0.0318	-0.0938**	0.1174+	0.0757	0.1004
	(0.0236)	(0.0242)	(0.0331)	(0.0630)	(0.0502)	(0.0642)
1970	0.0703*	0.0727*	-0.0449	0.0743	0.1040+	0.1663*
	(0.0303)	(0.0313)	(0.0406)	(0.0673)	(0.0542)	(0.0672)
1980	0.0940**	0.1030**	-0.0296	0.0385	0.1618**	0.1755*
	(0.0356)	(0.0382)	(0.0404)	(0.0693)	(0.0589)	(0.0696)
1990	0.1272**	0.1457**	0.0030	0.0769	0.2067**	0.2376**
	(0.0403)	(0.0441)	(0.0391)	(0.0722)	(0.0637)	(0.0754)
2000	0.1537**	0.1804**	0.0001	0.1106	0.2283**	0.2543**
	(0.0445)	(0.0483)	(0.0387)	(0.0750)	(0.0667)	(0.0784)

Panel B: *Property Values and Income*

	Property Values			Income Proxies	
	Log Med. Dwelling Value (Owner-Occ)	Log Med. Dwelling Rent (Renter-Occ)	Log Value Farmland and Farm Buildings	Log Retail Payroll per Worker	Log Mfg Payroll per Worker
	(7)	(8)	(9)	(10)	(11)
Early Access ×					
1960	0.0411*	0.0229	0.0168	0.0272*	0.0402
	(0.0208)	(0.0187)	(0.0219)	(0.0114)	(0.0260)
1970	0.0531*	0.0472*	0.0627**	0.0293*	0.0462+
	(0.0242)	(0.0194)	(0.0221)	(0.0132)	(0.0251)
1980	0.0697**	0.0522**	0.0892**	0.0314*	0.0489+
	(0.0257)	(0.0191)	(0.0235)	(0.0133)	(0.0273)
1990	0.0998**	0.0569**	0.1182**	0.0201	0.0575*
	(0.0274)	(0.0198)	(0.0301)	(0.0132)	(0.0286)
2000			0.1383**	0.0319*	0.0646*
			(0.0305)	(0.0138)	(0.0288)

Panel C: *Farm Outcomes*

	Log Farm Population	Log Farmland	Log Farm Revenue	Log Farm Rev. per Worker
	(12)	(13)	(14)	(15)
Early Access ×				
1960	-0.0717*	-0.0757**	0.0188	0.1127**
	(0.0283)	(0.0197)	(0.0347)	(0.0335)
1970	-0.0542	-0.1084**	0.1694**	0.2165**
	(0.0354)	(0.0271)	(0.0419)	(0.0579)
1980	-0.0010	-0.1101**	0.0806	0.1077*
	(0.0397)	(0.0316)	(0.0494)	(0.0506)
1990	0.0293	-0.1146**	0.0780	0.0832
	(0.0399)	(0.0327)	(0.0564)	(0.0510)
2000		-0.1274**	0.0578	0.0577
		(0.0349)	(0.0632)	(0.0602)

Notes: The sample is restricted to counties that experienced above-median decreases in distance to the nearest power plant between 1930 and 1960. The variable *Early Access* is a dummy for counties that experienced the majority of the decrease prior to 1940. Each column reports the point estimates from a different regression. All models include the full set of controls reported in Table 2. Standard errors are clustered at the county-level. **,*, + denote significance at the 1%, 5%, and 10% level, respectively.

Table 7: Long-run effects of early electricity access: Heterogeneity by distance to MSA I

	Pop. and Emp.		Property Values			Farm Outcomes		
	Log Pop.	Log Emp.	Log Med. Dwell. Value (Owner-Occ)	Log Med. Dwell. Rent (Renter-Occ)	Log Value Farmland & Buildings	Log Farm Population	Log Farmland	Log Farm Revenue per Worker
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Early Access × I(Near MSA) ×								
1960	0.0539	0.0434	0.0730*	0.0431	0.0670*	-0.1365**	-0.1245**	0.1357**
	(0.0366)	(0.0399)	(0.0345)	(0.0276)	(0.0316)	(0.0436)	(0.0278)	(0.0504)
1970	0.0845+	0.0773	0.0601+	0.0641*	0.0991**	-0.1543**	-0.1980**	0.2856**
	(0.0483)	(0.0517)	(0.0357)	(0.0273)	(0.0336)	(0.0545)	(0.0412)	(0.0898)
1980	0.1091+	0.1138+	0.1060**	0.0920**	0.1166**	-0.1279*	-0.2080**	-0.0662
	(0.0578)	(0.0629)	(0.0398)	(0.0280)	(0.0362)	(0.0619)	(0.0479)	(0.0790)
1990	0.1463*	0.1595*	0.1444**	0.0932**	0.1351**	-0.1313*	-0.2072**	-0.0128
	(0.0669)	(0.0733)	(0.0422)	(0.0294)	(0.0495)	(0.0623)	(0.0495)	(0.0878)
2000	0.1688*	0.1962*			0.1402**		-0.2237**	-0.0470
	(0.0742)	(0.0809)			(0.0489)		(0.0533)	(0.0927)
Early Access × I(Far MSA) ×								
1960	0.0185	0.0219	0.0141	0.0059	-0.0257	-0.0168	-0.0409+	0.0931*
	(0.0303)	(0.0293)	(0.0285)	(0.0253)	(0.0300)	(0.0350)	(0.0233)	(0.0438)
1970	0.0583	0.0688+	0.0471	0.0330	0.0318	0.0305	-0.0401	0.1580*
	(0.0380)	(0.0376)	(0.0318)	(0.0266)	(0.0303)	(0.0444)	(0.0305)	(0.0746)
1980	0.0811+	0.0938*	0.0391	0.0185	0.0662*	0.1063*	-0.0386	0.2552**
	(0.0437)	(0.0461)	(0.0324)	(0.0257)	(0.0309)	(0.0492)	(0.0353)	(0.0611)
1990	0.1111*	0.1341*	0.0620+	0.0262	0.1040**	0.1652**	-0.0472	0.1646**
	(0.0484)	(0.0521)	(0.0344)	(0.0261)	(0.0363)	(0.0486)	(0.0366)	(0.0550)
2000	0.1409**	0.1671**			0.1366**		-0.0587	0.1462+
	(0.0527)	(0.0563)			(0.0390)		(0.0389)	(0.0774)

Notes: The sample is restricted to counties that experienced above-median decreases in distance to the nearest power plant between 1930 and 1960. The variable *Early Access* is a dummy for counties that experienced the majority of the decrease prior to 1940. The variables *I(Near MSA* and *I(Far MSA* are indicators for counties within or beyond 60 miles from the nearest MSA. Each column reports the point estimates from a different regression. All models include the full set of controls reported in Table 2 excluding county distance to the nearest MSA. Standard errors are clustered at the county-level. **,*, + denote significance at the 1%, 5%, and 10% level, respectively.

Table 8: Long-run effects of early electricity access: Heterogeneity by distance to MSA II

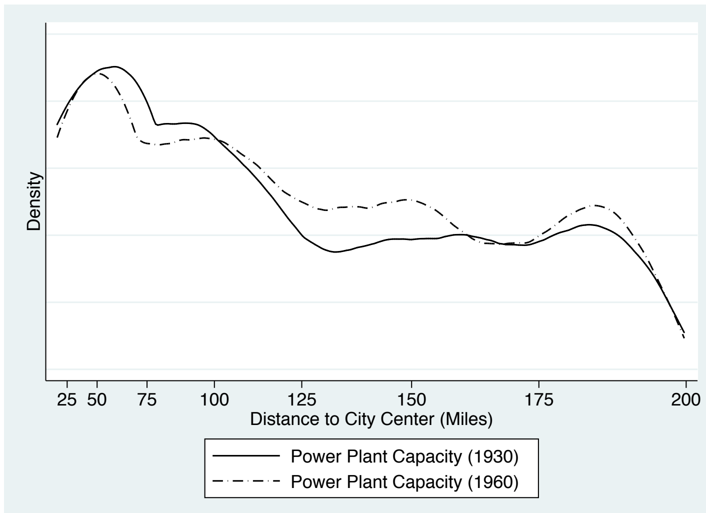
	Income proxies			Sorting		Amenities		
	Log Retail Payroll per Worker	Log Mfg. Payroll per Worker	Log Retail Sales per Capita	% White	% 25+ with HS Diploma	% Housing Units Built in Prev. Decade	Log Retail Emp.	Log Construction Emp.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Early Access × I(Near MSA) ×								
1960	0.0200	0.0593	0.0037	0.8726	0.6447	1.3916	0.0974	0.0626
	(0.0157)	(0.0369)	(0.0264)	(0.6916)	(2.1887)	(0.8983)	(0.0775)	(0.0989)
1970	0.0155	0.0654*	0.0328	1.1904	0.7754	2.0404*	0.1309	0.1441
	(0.0176)	(0.0331)	(0.0325)	(0.7434)	(0.8309)	(0.9792)	(0.0855)	(0.1073)
1980	0.0108	0.0532	0.0414	1.3206+	1.4961+	1.8762*	0.1791+	0.1436
	(0.0187)	(0.0418)	(0.0370)	(0.7602)	(0.8897)	(0.8946)	(0.0952)	(0.1131)
1990	0.0126	0.0528	0.0770+	0.8613	2.3544**	1.7032*	0.2116*	0.1951
	(0.0196)	(0.0405)	(0.0441)	(0.8012)	(0.8125)	(0.7907)	(0.1036)	(0.1232)
2000	0.0346+	0.0852*	0.0953+	-0.0415	1.7762*		0.2284*	0.2289+
	(0.0198)	(0.0383)	(0.0504)	(0.9217)	(0.7104)		(0.1098)	(0.1287)
Early Access × I(Far MSA) ×								
1960	0.0333*	0.0230	0.0226	0.2046	-3.6527	0.7757	0.0574	0.1315
	(0.0159)	(0.0357)	(0.0299)	(0.4887)	(3.3242)	(0.7693)	(0.0635)	(0.0809)
1970	0.0409*	0.0295	0.0173	-0.1514	-0.4423	2.0085*	0.0812	0.1845*
	(0.0183)	(0.0367)	(0.0335)	(0.4902)	(0.7319)	(0.7818)	(0.0676)	(0.0822)
1980	0.0488**	0.0453	0.0271	-0.1823	0.4371	1.4310*	0.1471*	0.2016*
	(0.0172)	(0.0347)	(0.0354)	(0.4858)	(0.6954)	(0.6930)	(0.0723)	(0.0833)
1990	0.0264	0.0615	0.0763+	-0.5111	0.9277	1.5608**	0.2026**	0.2724**
	(0.0167)	(0.0388)	(0.0400)	(0.5083)	(0.6388)	(0.5871)	(0.0776)	(0.0887)
2000	0.0297+	0.0466	0.0648	-0.7531	0.6658		0.2282**	0.2752**
	(0.0180)	(0.0391)	(0.0445)	(0.5956)	(0.5550)		(0.0796)	(0.0907)

Notes: The sample is restricted to counties that experienced above-median decreases in distance to the nearest power plant between 1930 and 1960. The variable *Early Access* is a dummy for counties that experienced the majority of the decrease prior to 1940. The variables *I(Near MSA* and *I(Far MSA* are indicators for counties within or beyond 60 miles from the nearest MSA. Each column reports the point estimates from a different regression. All models include the full set of controls reported in Table 2 excluding county distance to the nearest MSA. Standard errors are clustered at the county-level. **,*, + denote significance at the 1%, 5%, and 10% level, respectively.

A Appendix (For Online Publication)

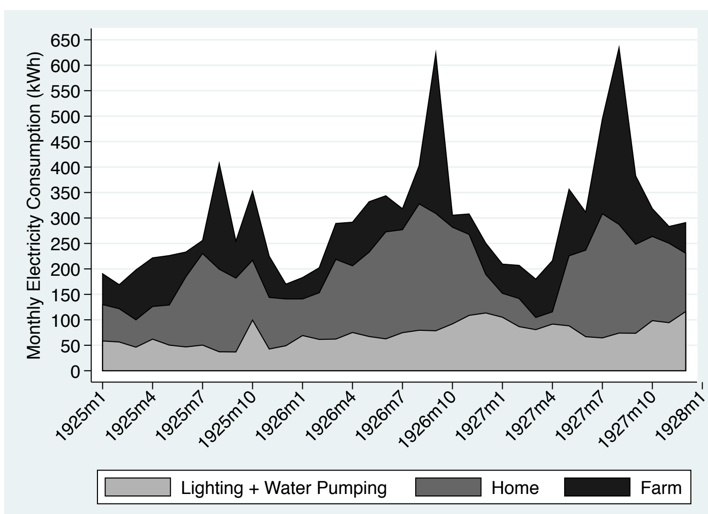
A.1 Figures and Tables

Figure A.1: Electricity Capacity Around 50 Largest Cities, 1930 and 1960



Notes: This figure reports the density of electricity capacity around the 50 largest U.S. cities in 1930 and 1960. The x-axis is scaled so that a uniform density within 200 miles of a city would be represented as a horizontal line in the figure.

Figure A.2: Electricity Consumption by Category – Red Wing Project, 1925-1927



Source: Author's calculation based on Stewart, Larson, and Romness (1927).

Figure A.3: The impact of an increase in electricity access on the rural sector

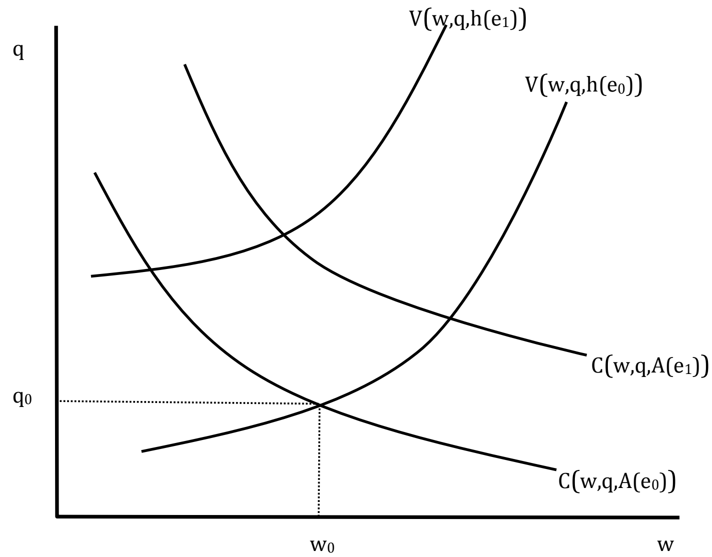


Table A.1: Proximity to Power Plants and Rural Electrification

	Dep. Var: % Farms with Electricity			
	(1)	(2)	(3)	(4)
Distance to Power Plant	0.517**	0.337**		
	[0.094]	[0.0090]		
I(Distance < 20 miles)			3.68**	2.31**
			[1.08]	[0.99]
I(20 < Distance < 40)			4.36**	2.66**
			[0.87]	[0.82]
I(40 < Distance < 60)			3.73**	2.34**
			[0.80]	[0.77]
I(60 < Distance < 80)			1.92*	0.92
			[0.87]	[0.82]
County & Year FE + State trend	Y	Y	Y	Y
Full controls		Y		Y
	N(Obervations) = 6,486		N(Counties)= 2,162	

Notes: This table reports the relationship between power plant distance and the percent farms with electricity for decennial years 1940, 1950, and 1960. In columns (1) and (2), distance is measured in -10s of miles. Columns (2) and (4) include the full set of controls from Table 2. Standard errors are clustered at the county-level. **,*, + denote significance at the 1%, 5%, and 10% level, respectively.

Table A.2: Robustness: Long-run effects of early electricity access

	Pop. and Emp.		Property Values			Farm Outcomes		
	Log Pop.	Log Emp.	Log Med. Dwell. Value (Owner-Occ)	Log Med. Dwell. Rent (Renter-Occ)	Log Value Farmland and Farm Buildings	Log Farm Population	Log Farmland	Log Farm Revenue per Worker
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: *Compare 'Early Access' (1930-1940) to 'Late Access' (1950-1960)*								
Early Access ×								
1960	0.0177	0.0178	0.0587*	0.0269	-0.0230	-0.0150	-0.0504*	0.0930*
	(0.0266)	(0.0258)	(0.0260)	(0.0246)	(0.0254)	(0.0314)	(0.0241)	(0.0386)
1970	0.0509	0.0479	0.0880**	0.0425	0.0154	0.0286	-0.0680*	0.0624
	(0.0346)	(0.0345)	(0.0321)	(0.0259)	(0.0255)	(0.0384)	(0.0301)	(0.0713)
1980	0.0746+	0.0784+	0.1042**	0.0518*	0.0405	0.1115*	-0.0438	0.1159+
	(0.0416)	(0.0438)	(0.0348)	(0.0251)	(0.0248)	(0.0464)	(0.0361)	(0.0621)
1990	0.0939*	0.1076*	0.1322**	0.0419+	0.0306	0.1188**	-0.0432	0.0381
	(0.0477)	(0.0517)	(0.0377)	(0.0252)	(0.0317)	(0.0425)	(0.0390)	(0.0602)
2000	0.1157*	0.1426*			0.0700*		-0.0526	0.0471
	(0.0535)	(0.0578)			(0.0330)		(0.0416)	(0.0736)
Panel B: *Diff-in-diff including rural counties with below-median decreases in distance ($\Delta DistPP$ 1930-1960)*								
DID: Early Access × Above-median decrease ×								
1960	0.0463	0.0438	0.0589*	0.0462*	0.0241	-0.0325	-0.0097	0.0668
	(0.0304)	(0.0338)	(0.0258)	(0.0223)	(0.0270)	(0.0342)	(0.0149)	(0.0409)
1970	0.0961*	0.0877*	0.0786**	0.0711**	0.0920**	0.0197	-0.0342	0.0805
	(0.0391)	(0.0429)	(0.0295)	(0.0231)	(0.0291)	(0.0482)	(0.0239)	(0.0740)
1980	0.1122*	0.1198*	0.0767*	0.0677**	0.0984**	0.0316	-0.0680*	0.1172
	(0.0451)	(0.0504)	(0.0321)	(0.0236)	(0.0309)	(0.0527)	(0.0294)	(0.0718)
1990	0.1564**	0.1740**	0.0981**	0.0735**	0.1237**	0.0937+	-0.0500+	-0.0016
	(0.0515)	(0.0579)	(0.0343)	(0.0246)	(0.0376)	(0.0518)	(0.0298)	(0.0636)
2000	0.1854**	0.2095**			0.1496**		-0.0399	0.0202
	(0.0571)	(0.0630)			(0.0393)		(0.0313)	(0.0823)

Notes: The variable *Early Access* is a dummy for counties that experienced the majority of the decrease prior to 1940. Each column reports the point estimates from a different regression. All models include the full set of controls reported in Table 2. Standard errors are clustered at the county-level. **,*, + denote significance at the 1%, 5%, and 10% level, respectively.

Table A.3: Long-run effects of early electricity access and highway access

	Pop. and Emp.		Property Values			Farm Outcomes		
	Log Pop.	Log Emp.	Log Med. Dwell. Value (Owner-Occ)	Log Med. Dwell. Rent (Renter-Occ)	Log Value Farmland & Buildings	Log Farm Population	Log Farmland	Log Farm Revenue per Worker
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Early Access to Electricity ×								
1960	0.0367	0.0337	0.0412*	0.0232	0.0175	-0.0718*	-0.0763**	0.1137**
	(0.0232)	(0.0238)	(0.0209)	(0.0187)	(0.0219)	(0.0284)	(0.0196)	(0.0334)
1970	0.0730*	0.0756*	0.0537*	0.0477*	0.0636**	-0.0537	-0.1089**	0.2157**
	(0.0296)	(0.0306)	(0.0242)	(0.0194)	(0.0222)	(0.0355)	(0.0271)	(0.0580)
1980	0.0985**	0.1068**	0.0704**	0.0526**	0.0896**	-0.0004	-0.1109**	0.1082*
	(0.0350)	(0.0373)	(0.0258)	(0.0191)	(0.0235)	(0.0399)	(0.0315)	(0.0507)
1990	0.1314**	0.1505**	0.1009**	0.0576**	0.1193**	0.0300	-0.1154**	0.0820
	(0.0394)	(0.0429)	(0.0274)	(0.0198)	(0.0301)	(0.0401)	(0.0327)	(0.0507)
2000	0.1585**	0.1859**			0.1392**		-0.1280**	0.0581
	(0.0434)	(0.0469)			(0.0305)		(0.0349)	(0.0603)
1944 Interstate Highway Plan ×								
1960	0.1188**	0.1170**	0.0091	0.0183	0.0425*	-0.0045	-0.0369	0.0617
	(0.0254)	(0.0258)	(0.0202)	(0.0174)	(0.0213)	(0.0271)	(0.0239)	(0.0391)
1970	0.1634**	0.1780**	0.0382+	0.0256	0.0659**	0.0322	-0.0353	-0.0558
	(0.0320)	(0.0329)	(0.0216)	(0.0166)	(0.0231)	(0.0311)	(0.0281)	(0.0553)
1980	0.2006**	0.2323**	0.0370	0.0265	0.0292	0.0358	-0.0524+	0.0283
	(0.0366)	(0.0392)	(0.0234)	(0.0170)	(0.0257)	(0.0340)	(0.0315)	(0.0508)
1990	0.2520**	0.2887**	0.0641**	0.0437*	0.0689*	0.0553	-0.0469	-0.0843+
	(0.0413)	(0.0448)	(0.0246)	(0.0173)	(0.0302)	(0.0337)	(0.0329)	(0.0495)
2000	0.2930**	0.3307**			0.0561+		-0.0379	0.0258
	(0.0444)	(0.0482)			(0.0327)		(0.0336)	(0.0564)

Notes: The sample is restricted to counties that experienced above-median decreases in distance to the nearest power plant between 1930 and 1960. The variable *Early Access* is a dummy for counties that experienced the majority of the decrease prior to 1940. The variable *1944 Interstate Highway Plan* is an indicator for whether the planned interstate intersected the rural county (based on Michaels, 2008). Each column reports the point estimates from a different regression. All models include the full set of controls reported in Table 2. Standard errors are clustered at the county-level. **,*, + denote significance at the 1%, 5%, and 10% level, respectively.

A.2 A Two-Sector Rosen-Roback Model of Rural Electrification

To study the effects of rural electrification on local economies in the U.S., we outline a Rosen-Roback style model with two production sectors (Roback, 1982): rural production (agriculture), $s = R$, and urban production (manufacturing), $s = U$. We consider a setting with a large number of counties, each with a fixed supply of land. Workers are fully mobile across counties, but must work in their county of residence. Local labour mobility implies that urban and rural wages will equalize within each county,[37] whereas differences in housing amenities across urban and rural areas can lead to intra-county differences in land prices.

Workers are assumed to have identical preferences over a consumption commodity, x, residential land, l^s, and housing quality, h^s. The local wage and rental rate are denoted by w and q^s, where the latter may differ across urban and rural areas. The worker's indirect utility function, V, depends on prices, w and q^s, and housing quality, h^s. The equilibrium condition for workers is given by:

$$V\big(w, q^s, h^s\big) = v \quad \text{for} \quad s \in \{R, U\} \tag{A.1}$$

where v denotes the reservation utility of moving to another county. This condition states that wages and rental costs must equalize utility across counties and across sectors. Despite perfect labour mobility, wages need not equalize across counties, due to differences in housing quality and costs.

In both sectors, firms are assumed to produce a consumption commodity, X^s, which is sold to the world market at a price normalized to one. We assume that X^s is produced according to a constant-returns-to-scale production function, $X^s = f(l^s, N^s, A^s)$, where l^s denotes land used in production, N^s denotes the workers employed in sector, s, and A^s is a sector-specific technology.[38] In equilibrium, firm profits must equal zero in all sectors and counties, otherwise firms have an incentive to relocate. Under the constant-returns-to-scale assumption, the equilibrium condition implies that the unit cost must be equal to the output price:

$$C(w, q^s, A^s) = 1 \quad \text{for} \quad s \in \{R, U\}. \tag{A.2}$$

Equilibrium prices, $\big(w, q^R, q^U\big)$, are determined by the local housing amenities, h^R and h^U, sector technologies, A^R and A^U, and the worker's outside option, v.

A.2.1 The impact of rural electrification on the rural and urban sectors

This simple framework can be used to evaluate the effects of electrification on employment and population outcomes. Denote e as a measure of local electricity access (e.g., the fraction of farms with electricity). We assume that rural electrification

[37] The assumption of common wages can be relaxed to allow for heterogeneous worker productivity across sectors. In this case, rural electrification has a common effect on local wages, despite the fact that initial wage levels may differ across sectors.

[38] Since capital is fully mobile it can be 'optimized out' of the location problem.

can potentially affect the rural sector through increases in agricultural productivity, ${A^R}'(e) > 0$, and improvements in rural housing quality, ${h^R}'(e) > 0$. On the other hand, urban sector productivity and housing quality are not directly affected by rural electrification.

Figure A.3 depicts the rural equilibrium at an initial level of electricity access, e_0. To simplify notation, the sector superscripts are omitted. The downward-sloping curve $C\big(w, q, A(e_0)\big)$ displays the combinations of q and w that satisfy condition (2) – equating the producer's unit cost function to the output price – given agricultural technology, $A\left(e_0\right)$. The upward-sloping curve, $V\big(w, q, h(e_0)\big)$, depicts the combinations of q and w that satisfy the worker's equilibrium condition at housing quality $h(e_0)$, in which indirect utility is equal to the reservation value of moving.[39] Initial equilibrium prices are determined by the intersection of these curves at $\big(w_0, q_0\big)$.

Consider an expansion in rural electricity access to e_1. If electricity improves agricultural productivity but has no impact on the quality of rural housing – e.g., $A(e_1) > A(e_0)$ and $h(e_1) = h(e_0)$ – then an expansion in access will lead to an influx of agricultural producers driving up the price of rural land, q.[40] Because rural workers derive no direct benefits from this technology, they must be compensated for the increased cost of housing with a higher wage. This situation is depicted by the upward shift in the firm's unit cost function to $C\big(w, q, A(e_1)\big)$. Equilibrium is restored at the point where the new cost curve intersects the original indirect utility function. In this scenario, rural electrification leads to increases in local wages and land values. Overall, the rural sector will expand, as will agricultural land and employment.[41]

If electricity access affects rural housing quality but has no impact on agricultural productivity, rural workers must compensate producers for the rise in land costs. This situation is captured by the leftward shift in the indirect utility function to $V\big(w, q, h(e_1)\big)$, in which rural electrification leads to increases in rural land prices and decreases in wages. Employment in the rural sector should rise, although it will be somewhat mitigated by increased demand for land for rural housing.

When electricity access increases both rural housing quality and agricultural productivity, we should observe large increases in local land prices but ambiguous effects on wages. This situation is captured by a shift in both the cost function and the indirect utility curve. Improvements in housing quality will attract rural workers and improvements in agricultural technology will attract rural producers, which will drive up local land values. The net effect on the wage is ambiguous, and depends on the relative size of these two shifts. Overall, the rural sector should expand, as should

[39] The curvature of these functions depends on the degree of complementarity in production (between labour and land) and utility (between consumption and land).

[40] The effects on agricultural land price and land use will depend on the elasticity of demand for land in the urban sector.

[41] In principle, electricity could lead to a reduction in agricultural employment if it is a "strongly labour-saving" technology which lowers the marginal product of rural labour (Acemoglu, 2010). Even if electricity is a capital-augmenting technology (rather than factor neutral), we require both decreasing returns to scale and a high elasticity of substitution between capital and labour for this situation to arise. Intuitively, given that electricity increases the total amount of land in farming, strong substitution forces are needed to overwhelm the upward pressure on employment.

agricultural land and employment.

Although changes in rural electrification do not directly impact urban residents or producers, they can have indirect effects on the urban economy through local factor prices. Given a fixed supply of land in each county, an increase in the demand for agricultural land will drive up the urban land price, q^U. Local mobility also requires that the urban wage move in tandem with the rural sector. In urban areas, the rise in housing costs caused by rural electrification will not be offset by improvements in housing quality or fully compensated by higher wages. As a result, rural electrification should lead to a relative decline in the local urban population. Moreover, the rise in land and labour costs should lead to a decrease in urban production. Over time outmigration will offset the upward pressure on housing prices, restoring equilibrium at lower levels of urban population, employment, and production.

A.2.2 Calculating the value of electricity to rural producers and rural residents

The previous results can be used to evaluate the amenity and production values associated with rural electrification. Define $p_e^* \equiv V_e/V_w$ as the amount of income required to compensate an individual for a change in electricity access. This variable captures the amenity value of rural electricity associated with improvements housing quality. Differentiating equations (1) and (2) and solving for dw/de and dq/de it can be shown that:

$$\frac{p_e^*}{w} = k_l \cdot \frac{d\log q}{de} - \frac{d\log w}{de} \tag{A.3}$$

where k_l denotes the fraction of the households budget spent on land. Equation (3) states that the amenity value of electricity can be calculated based on the relative change in local land prices and wages. Intuitively, when electricity access leads to large increases in housing prices relative to wages, workers must directly benefit from this technology. Specifically, p_e^*/w denotes the percent of income that households would be willing to forgo for access to electricity. Since k_l, $\frac{d\log q}{de}$, and $\frac{d\log w}{de}$ are observable, this expression can be used to derive the amenity value of electricity.

Turning to the benefits of electricity for rural productivity, the marginal impact of electricity on producers' unit costs, C_e, is given by:

$$C_e = -\left(\theta_w \frac{d\log w}{de} + \theta_q \frac{d\log q}{de}\right), \tag{A.4}$$

where θ_w and θ_q are the shares of labour and land in the cost of production. Since all right-hand-side variables are observable, we can estimate the productivity benefits associated with rural electrification.

Finally, the aggregate benefit of electricity to the rural sector can be constructed as the summation of the willingness-to-pay across the rural population, N^R, plus the cost-savings across all agricultural goods, X^R, as follows:

$$p_e^* N^R + \big[- C_e X^R \big] = \frac{dq}{de} L^R. \tag{A.5}$$

The aggregate willingness-to-pay for electricity is given by the change in rural land prices times the total land in the rural sector. Because the wage effects on rural workers and producers exactly offset, this measure does not depend on wages.