

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

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Abstract

This study exploits the historical rollout of the U.S. power grid between 1930 and 1960 to examine the evolving impacts of rural electrification on the local economy. Rural electrification led to a short-run expansion of the agricultural sector, and brought benefits to rural residents that exceeded the historical costs of extending the grid. Rural counties that gained early access to electricity experienced economic growth that lasted decades after the country was fully electrified. In rural counties located relatively near metropolitan areas, the expansion was driven by nonagricultural sectors, suggesting that, over time, rural electrification fuelled suburban growth.

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1 Introduction

Investment in large scale infrastructure has long been considered a transformative force for the economy (e.g., Rostow, 1960; Rosenstein-Rodan, 1961; Murphy, Shleifer, and Vishny, 1989). Currently, one third of international development lending is devoted to major infrastructure projects. Electrification figures prominently among these projects because 1.2 billion people worldwide still lack access to electricity (IEA, 2016). Historically, expansions in the power grid also played a key role in bringing electricity to rural America during the mid-20th century. Economists have begun studying the impacts of electrification on various economic outcomes but the evidence has been mixed, in part because electricity offers a range of benefits that are difficult to quantify and not captured by standard economic indicators.¹ Moreover, as with many large scale infrastructure projects, short-run evaluations may fail to capture the transformative effects of electrification that could take several decades to emerge (Devine Jr., 1983; David, 1990).

This paper proposes a new approach to assess the short-run benefits of electricity access taking into account non-market amenities, and provides the first estimates of the long-run impacts of rural electrification on the local economy. Our approach combines a standard spatial equilibrium model (Rosen, 1979; Roback, 1982) with difference-in-differences effects on farmland values, housing prices, incomes, and a range of other local outcomes characterizing the immediate effects of electricity access on the rural sector. These estimates are obtained by exploiting the spatial pattern of the historical rollout of the U.S. power grid between 1930 and 1960. To track the evolving long-run impacts of rural electrification, we use a difference-in-differences strategy relying on detailed data for a range of outcomes over the period 1930 to 2000, and the timing of electricity access over the three decades of grid expansions.

The historical U.S. context provides an exceptional opportunity to study the effects of rural electrification. While urban areas were almost fully electrified by 1930, more than 90 percent of rural households gained access to electricity between 1930 and 1960, and there were sharp differences in the timing of rural electrification driven by plausibly exogenous factors related to the cost of extending services. Moreover, these expansions occurred at a time when even poor households had access to credit for purchasing electric appliances and home retrofitting, allowing us to evaluate the benefits of electrification in a setting in which households can take full advantage of

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

the technology.² In addition, the historical U.S. censuses provide information on a rich set of county-level outcomes, which combined with the 70-year historical time horizon, allow us to identify adjustments that occurred gradually over an extended period of time.

The empirical analysis combines a panel dataset on county-level outcomes with a newly digitized dataset that provides detailed information on the location and characteristics of large power plants that opened between 1930 and 1960. We use county-centroid distance to the nearest power plant as our measure of electricity access. Proximity to plants played an important role in determining which rural communities electrified.³ Our identification assumption – that rural counties would have evolved similarly in the absence of changes in 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.⁴ Second, the amount of electricity generated by these plants relative to rural demand.⁵ Third, the fact that baseline rural population characteristics are generally unrelated to subsequent power plant openings.

We have two main findings. First, using a generalized difference-in-differences strategy à la Card (1992) and Acemoglu, Autor, and Lyle (2004) that controls for differential trends based on initial demographic and economic conditions of each county and its nearest MSA (the latter to control for potential “boom town” spillovers), we show that a reduction in distance to a large power plant led to short-run (within a decade) increases in farmland values and an expansion in the rural sector, but had little impact on various income proxies and did not generate spillovers onto nonagricultural sectors. The results are robust to a range of specifications and samples. In a standard spatial equilibrium model, these reduced-form estimates imply that rural electrification led to large gains in rural welfare driven by both improvements in agricultural productivity

²In 1934, the Roosevelt administration established the Electric Home and Farm Authority (EHFA) and the Federal Housing Administration (FHA). These programs provided low interest loans to households for purchasing modern household appliances and retrofitting homes for electrical services. REA’s studies indicated that the average investment in wiring and electric appliances corresponded to roughly 75 percent of the typical annual farming income over the period 1930-1960 (Saulnier, Halcrow, and Jacoby, 1958).

³Distance to the grid was an important determinant of the Rural Electrification Administration (REA) loan approval process (Fishback and Kitchens, 2015).

⁴Electric utilities faced severe constraints on where plants could be built. Hydroelectric plants were ideally located at narrow points along a river that had consistent water flow throughout the year and a sufficient gradient. Meanwhile, coal-fired power plants needed to locate near a source of coal and a large body of water for coolant (Hughes, 1993).

⁵Given the limits of electricity transmission and low rural electricity consumption, we calculate that less than 10 percent of total power plant generation could have been used by rural customers.

and the non-market amenity of improved rural housing.⁶ We calculate that the average rural family would have been willing to forgo 27 percent of annual income to live in a home equipped with electrical services. Given the large upfront and operating costs of home generators, these gains were likely not large enough to justify individual farm electrification.⁷ Nevertheless, we calculate that the benefits exceeded the historical costs of extending the grid even at population densities of less than three farms per mile of distribution line.

Second, adopting a difference-in-differences approach that compares relative outcomes across early versus late electrifying rural counties with similar observable characteristics in 1930, we show that these two groups of counties diverged in the post-1960 period, when the U.S. was fully electrified. Although those counties were similar along baseline outcomes and pre-1930 trends, early electrifying counties experienced persistent relative growth in population and employment in the period 1960 to 2000. By 2000, early electrifying counties were 16 percent more populous than observationally similar late electrifying counties. This expansion was not driven by the agricultural sector. Instead, employment growth was concentrated in construction, services, and trade sectors, suggesting that the temporary local advantage of early electrification spurred broader local development. Relative growth in local property values and income proxies in early electrifying counties is also consistent with this interpretation.

Why did early electrifying rural areas experience persistent growth even after the country was fully electrified? We find that the effects on population, employment, and farmland values were economically sizable in both rural counties located near and far from metropolitan areas. For near-MSA counties, the temporary local advantage of early electrification appears to have helped resolve a residential coordination problem, concentrating mid-20th century suburbanization into particular rural areas which subsequently spurred long-term local development. In fact, farmland area reduced considerably in those counties, and housing prices rose. Residential segregation reinforced those migration patterns. Workers who moved to early electrifying rural counties near MSAs had higher levels of education, seemed disproportionately white, earned higher incomes, and consumed more local amenities. Together, these results suggest that suburban growth was an important channel through which early electrification influ-

⁶Intuitively, higher land values could capture either increased farm productivity or improvements in rural housing quality. The relative size of these two effects depends on the response in rural wages. On the one hand, improvements in housing quality will drive down rural wages, as workers are willing to accept lower wages given the non-market amenities associated with electrification. On the other hand, increases in agricultural productivity will drive up rural wages as producers seek to attract more productive rural workers.

⁷Less than 4 percent of farms owned generators in 1930 (Nye, 1990).

enced the long-run population distribution.⁸ More remote counties also experienced local economic growth, but driven by the agriculture sector. We find that agricultural productivity increased, and more land was devoted to farming. At the same time, nonagricultural, nontradable sectors flourished: construction and retail employment increased substantially. Overall, it seems that the growth in the rural sector spilled over the local urban areas.

This paper makes two important contributions to the literature. First, it provides a new approach to evaluate the short-run benefits of electricity access that incorporates non-market amenities. The resulting estimates help reconcile the mixed evidence on the impacts of rural electrification in both the historical and the developing country context. Some previous studies have estimated positive effects of rural electrification on agricultural output (Kitchens and Fishback, 2015; Chakravorty, Emerick, and Ravago, 2016), local development (Lipscomb, Mobarak, and Barham, 2013; Severnini, 2014), female employment (Dinkelman, 2011; Lewis, 2016a), and health (Clay, Lewis, and Severnini, 2016; Lewis, 2016b)⁹, while others have shown modest or potentially negative impact on the local economy (Burlig and Preonas, 2016; Lee, Miguel, and Wolfram, 2016). Our hedonic results suggest that expansions in electricity access brought large benefits to the rural residents, however, because many of these gains occurred within the household, they are unlikely to be fully captured by standard economic indicators.

Second, our study highlights the importance of long-run evaluations of rural electrification infrastructure investments. Because adjustments occur over a period of decades, short-run assessments will not identify the full impacts of these investments. We add to a growing literature that uses historical settings to identifying adjustments that occur over long periods of time (e.g., Davis and Weinstein, 2002; Redding and Sturm, 2008; Hornbeck, 2012). We show that endogenous responses to electrification ultimately led to persistent differences in long-run outcomes even after the technology was universally adopted. These findings also complement previous studies that document persistent effects of temporary natural advantages and place-based policies (e.g., Bleakley and Lin, 2012; Kline and Moretti, 2014¹⁰). This study adds electrification to a list of large scale infrastructure projects that have a transformative impact on the local economy such as major railways (e.g., Haines and Margo, 2008; Atack et al., 2010; Atack and

⁸The results are robust to controls for the interstate highway system (Baum-Snow, 2007). In particular, we find that both early rural electrification and planned interstate highway expansions had *distinctive* effects on population and employment growth.

⁹A related literature examines the effects of improvements in reliability of rural services (e.g., Chakravorty, Pelli, and Marchand, 2014; Ryan, 2014).

¹⁰Although electrification was part of the bundle of infrastructure projects considered in Kline and Moretti (2014), their focus was on agglomeration driven by manufacturing.

Margo, 2011; Banerjee, Duflo, and Qian, 2012; Donaldson, 2013; Donaldson and Hornbeck, 2016), highways (e.g., Baum-Snow, 2007; Michaels, 2008; Duranton, Morrow, and Turner, 2014; Faber, 2014), and dams (e.g., Duflo and Pande, 2007; Strobl and Strobl, 2011; Lipscomb, Mobarak, and Barham, 2013; Severnini, 2014).

This paper also proposes a new determinant of U.S. suburbanization. Baum-Snow (2007) provides evidence that the construction of the interstate highway system caused suburbanization. Boustan (2010) shows that the postwar suburbanization was a “white flight”. We argue that rural electrification influenced the geographic pattern of suburbanization by resolving a coordination problem during a period of high population mobility.¹¹

The paper proceeds as follows: Section 2 provides a historical background about the rural electrification in the U.S. Section 3 introduces a conceptual framework to highlight potential effects of rural electrification on local economies. Section 4 describes the data used in our analysis. Section 5 presents our empirical strategy to examine the impact of rural electrification in the short and long run. Section 6 reports our results, and provides interpretation in light of the conceptual framework. Section 7 offers concluding remarks.

2 Historical Background

In this section, we describe the increase in rural electricity access between 1930 and 1960. We also document the expansion of the U.S. power grid during this period, and discuss its impact on rural electrification rates. Finally, we draw on a unique historical case study of rural electrification to discuss the potential uses of electricity on the farm.

2.1 Rural Electrification in the U.S.

Electrification in urban and rural areas occurred in distinctive periods. Figure 1 reports electrical services for nonfarm and farm households between 1900 and 1960. The fraction of urban households with electricity rose sharply during the first three decades of the 20th century. By 1930, 85 percent of urban and rural non-farm residents were wired for electricity, and virtually every major city and town was electrified. Meanwhile,

¹¹The role of electrification in driving suburban expansion has been recognized by historians. Nye (1993, p.327) argues 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... The result was not a pastoral utopia like Howell’s Altruria, but rather the sprawling “crabgrass frontier” of an extended suburbia.”

fewer than 10 percent of farms were electrified by 1930. Over the next 25 years, there was a sharp increase in rural electrification rates, with the proportion of farms with electrical services reaching 95 percent in 1955.

Throughout the 1920s, private power companies were 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). These beliefs were reinforced by several well-publicized experiments in the 1920s, which found that it was unprofitable to extend services to rural customers.¹²

During the 1930s, the federal government introduced several programs to promote rural electrification. In 1933, the Roosevelt administration created the Tennessee Valley Authority (TVA), which offered local rural residents access to low cost electricity, and by 1952 the TVA was supplying electricity to 175 counties in seven states (Kitchens, 2014). In 1935, the Rural Electrification Administration (REA) was established. This agency provided low-interest loans for the construction of power lines into rural areas and to wire farms for electricity. Over the next 25 years, the REA funded over 1.4 million miles of distribution lines, and serviced over 4.8 million rural customers (Historical Statistics of the U.S., 1976).¹³ These programs, combined with the gradual expansion of rural services provided by the private sector, led to large increases in the proportion of farms that were electrified.

2.2 Expansion in the U.S. Power Grid and Rural Electricity Access

In the early 20th century, electricity was produced and consumed locally. Limitation in transmission technology meant that generation needed to occur near the site of consumption, and power plants were typically built near urban areas with virtually no interconnection of the power grid across markets. As transmission technology improved, electric utilities were less constrained in the siting of power plants.¹⁴ In the years after World War I, electric utilities began integrating power plants into a grid that supplied multiple markets, allowing them to smooth across local peaks in electricity demand and increase overall reliability of services (Hughes, 1993, p.324). With this shift, new

¹²For example, the National Electric Light Association (NELA) supervised the construction of twelve rural lines in 1923 to serve 359 families. The experiment lost \$8,000 on a \$94,000 investment (NELA, 1925).

¹³Other major federal projects, such as the Bonneville dam power plant, offered new sources of electricity to rural residents.

¹⁴Maximum transmission voltages increased from less than 50 kilovolts in 1900 to over 150 kilovolts in the 1920s (Casazza, 2004, p.10).

power plants were increasingly built outside of urban areas (see Figure A.1).

Advances in transmission technology also allowed power plants to be sited increasingly on the basis of cost considerations. 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. Local characteristics were a key determinant of the construction costs and ongoing operating costs of power plants. Coal-fired plants accounted for three-quarters of electricity generation during this period (Historical Statistics, 1976, p.820). In 1930, roughly 1.6 pounds of coal was burned for each kilowatt-hour of electricity generation (Historical Statistics, 1976, p.826). Thus, a 30 MW coal-fired power plant operating at full capacity would have burned over 500 tons of coal per day. Plant operating costs depended on the distance coal had to be shipped, since freight costs typically accounted for two-thirds of the total cost of shipped coal (*Electrical World*, 1938). Access to a large supply of water for coolant was also essential to coal-fired power plant efficiency.¹⁵ There were even greater constraints on the siting of large hydroelectric power plants. These plants needed to be located at a narrow point along a river that had a consistent water flow throughout the year and a sufficient gradient.

Figure 2 reports the map of power plants that opened before 1930 and power plants that opened between 1930 and 1960. There were strong regional patterns in power plant construction. In 1930, there had already been substantial development in the Northeast and in California, although few plants had been built in the Midwest or South. Between 1930 and 1960, more than 600 large power plants opened. New plants continued to be opened in the West throughout the Northeast. There was also significant development throughout the South and Midwest, and by 1960, there was wide coverage throughout the country.

The non-uniform expansion of the power grid led to differential changes in the cost of extending rural electricity access. Rural demand for electricity was far too small to have influenced the siting decisions of these large plants – the typical power plant would have produced roughly 10 times the amount of electricity that could have been consumed by all potential rural customers.¹⁶ Nevertheless, once built, these plants had a significant impact on rural electricity access. Proximity to power plants was an

¹⁵For every pound of coal, 400 pounds of cooling water were used, and water temperature played a crucial role in the performance of steam turbines (Hughes, 1993, p.306).

¹⁶This 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.

important determinant of access, given that electric utilities were responsible for the construction and maintenance of transmission lines, and power losses are a function of transmission distance. Moreover, 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).

2.3 Uses of Electricity on the Farm and in the Home

Electricity offered a range of benefits to farm production. By 1960, more than 100 different types of farm machines driven by electric motors were in use on American farms. Electric milking machines reduced milking time by 50 percent and directly pumped milk into cooled storage tanks which reduced spoilage (Nye, 1990). Electric heaters and lights improved chicken and egg production. In Western states, access to pumped water led to large increases in farm irrigation.

Electricity also brought many benefits to rural households. Electric lighting extended the day and reduced exposure to smoke from kerosene lamps. Electricity provided access to a range of labor-saving appliances, which dramatically reduced the time of home production. Evidence from historical time use studies suggest that washing machines alone saved roughly nine hours per week on housework, and pumped water saved rural housewives from walking roughly one mile per day to collect water (USDA, 1944; Wilson, 193-).¹⁷

Federal programs that provided widespread consumer credit allowed virtually all American households, including low income households, to take advantage of this new technology. 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 goal of the EHFA was to overcome the “four main obstacles to widespread utilization of electric power: high electric rates, high appliance costs, high finance charges, and the ‘public’s lack of information relative to the use of electricity and electrical appliances’” (Coppock, 1940, p.11). Approximately 3 million rural customers were eligible for loans under the EHFA.¹⁸ The FHA also provided home

¹⁷Despite major changes in household technologies, time spent in home production remained roughly constant between 1920 and 1960 (Ramey, 2009), and that time savings was reallocated towards investment in child health (Lewis, 2016b).

¹⁸The typical down payment for appliance purchases was 15 percent of the average cash selling price. The average length of the contract was 30 months, and the average monthly payment represented less than 5 percent of the monthly income for the majority of the beneficiaries (Coppock, 1940).

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. Historians have emphasized the importance of this program in allowing low income households to take full advantage of the benefits associated with electrical modernization (Tobey, 1996). Indeed, studies made by the REA indicated that the average investment in wiring and electric appliances was approximately \$7,361 (1990 USD) (Saulnier, Halcrow, and Jacoby, 1958, p.231), about 75 percent of the typical annual farming income over the period 1930-1960. Between 1934 and 1937, the FHA insured about 1,450,000 modernization loans.¹⁹ Roughly two-fifths of the loaned funds were used for the purchase and installation of equipment and machinery, while three-fifths went for home additions, alterations, or repairs.

The wide range of new technologies afforded by electrification and the way in which they might interact makes it difficult to establish the specific channels through which electrification affected production on the farm and in the home. 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.”

The “Red Wing Project”. To provide case study evidence on the potential uses of electricity on the farm, we collected data from the Red Wing rural electrification project (Stewart, Larson, and Romness, 1927). The Red Wing Project ran from late 1923 to early 1928 in Red Wing, Minnesota. Eight participating farms received electrical services along with free access to a variety of household appliances and electrical farm equipment (see Table A.1 for the list of appliances and equipment).²⁰ We collected monthly data on electricity consumption by specific appliance and farm machinery for Red Wing participants.

Figure A.2 shows the monthly pattern for farm, home, and basic (lighting and pumping) electricity consumption. Household and basic electricity accounted for 70 percent of farm consumption.²¹ Household electricity consumption was relatively stable throughout the year, except for seasonality in refrigerator use: households seemed to turn off the fridge during winter months. Farm consumption displayed the greatest

¹⁹Although insured loans could run as long as 5 years, the average duration was 30 months.

²⁰The project was run by the University of Minnesota in collaboration with the local power company and manufacturers of electrical equipment and appliances. The local power company set a service charge of \$6.90 per month plus 5 cents per kWh for the first 30 kWh, and 3 cents per kWh for additional use. These rates were set to cover overhead and all variable costs based on an average of three customers per mile.

²¹There were large differences in electricity use across farms. The farm share ranged from 0.07 to 0.48, primarily because of differences in the intensity of dairy production.

variability, peaking during the harvesting season for barley, corn, oats, and wheat, around August-September in Minnesota (USDA, 1997).

Total electricity consumption among Red Wing participants was 50 percent higher than initially predicted, exceeding the national average of 35 kWh per month (U.S. Census Bureau, 1976).²² Electricity consumption was concentrated in the home and remained fairly stable throughout the year, mitigating the challenges of providing electricity to meet variable loads. The results of the Red Wing Project were influential in the federal government’s decision to support rural electrification, by suggesting that electricity was highly valued on the farm, and casting doubt on the long-held view that it was uneconomical to expand rural access.

3 Conceptual Framework

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

Short-Run Effects of Rural Electrification. The standard Rosen-Roback spatial equilibrium model (see details in Appendix A.2) can be used to evaluate the benefits associated with rural electrification through its impact on local property values and wages (Rosen, 1979; Roback, 1982).²³ There are a large number of counties, each with a fixed supply of land. Two sectors (agriculture and industry) produce tradeable goods using labor and land as inputs. Workers supply labor, and have preferences for a composite consumption commodity, residential land, and housing quality. Workers and firms are freely mobile across sectors and counties, and land values and wages are set such that all markets clear.

Rural electrification is assumed to affect the local economy through two potential mechanisms: i) increases in the productivity of the agricultural sector, and ii) improvements in the quality of rural housing. These two mechanisms will increase demand for farmland and attract workers and producers to the rural sector. The relative impacts of

²²The large gap can likely be attributed to the fact that households in the Red Wing Project were provided free access to a range of appliances. Meanwhile, prior to widespread credit under EHFA and FHA, the median electrified American home owned only a single major appliance.

²³Dinkelman and Schulhofer-Wohl (2015) proposes an alternative approach to evaluating welfare benefits of new electricity infrastructure in the absence of land markets, a situation typical of developing countries. They show that welfare bounds depend on income and migration responses, and that migration reduced gains from South Africa’s rural electrification program by 40%.

rural electrification on land prices and total farmland depends on the supply elasticity of rural land.²⁴

The relative impact of electricity access on land values and wages can be used to identify the benefits to rural communities driven by increases in agricultural productivity and improvements in the quality of rural housing. An increase in agricultural productivity will drive up local land values and the cost of rural housing. In the absence of improvements in rural housing quality, workers must be compensated for these costs with a higher wage. Similarly, improvements in the quality of rural housing will drive up local land prices. Without improvements in agricultural productivity, producers must be compensated for the increase in costs through lower wages, which workers will be willing to accept given the improvements in local rural housing quality.

Figure A.3 provides a graphical representation of the predicted local impact of rural electrification. The downward-sloping curve denotes combinations of wages w and rental rates q that equalize unit costs C at a level of electricity access e . The upward-sloping curve denotes the combinations of w and q for a level of electricity access, e , for which worker's indirect utility is constant and equal to the outside option of moving to another county, V^* . The initial spatial equilibrium occurs at the intersection of these two curves at prices w_0 and q_0 . Improvements in agricultural productivity associated with electrification will lead to a rightward shift of the unit cost curve. If workers do not benefit from improvements in housing quality, they must be compensated for the increase in housing costs with higher wages, and the new equilibrium is characterized by the intersection between the original indirect utility curve and the new unit cost curve with higher land prices and higher wages. Conversely, improvements in housing quality will lead to a leftward shift of the indirect utility curve, and equilibrium will be restored at higher land prices and lower wages. The model delivers two simple equations based on reduced form impacts of rural electrification on local land prices and wages that allow us to decompose the benefits to rural communities driven by increases in agricultural productivity and improvements in rural housing quality.

Rural electrification can also affect the industrial sector through changes in local prices. On the one hand, the rise in local property values may crowd-out activity in the industrial sector. On the other hand, an expansion in the agricultural sector could positively affect the non-agricultural sector through either production complementarities or increased demand for local non-tradeable goods. Thus, the overall effect on non-farm population and employment is ambiguous.

²⁴If the supply of rural land is inelastic, rural electrification can lead to large increases in land prices without having effects on total farmland.

Long-Run Impact of Early Rural Electrification. In the short-run, rural counties that gained early access to electricity are predicted to have experienced a relative expansion. It is theoretically ambiguous, however, whether these initial advantages persisted in the post-1960 period, after 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 and the temporary local advantage is eliminated. This situation is likely to arise in settings with homogeneous preferences over neighbors and local amenities, and weak economies of density. The speed of adjustment back to the long-run equilibrium will depend on whether early electricity spurred endogenous local investments. Historians have emphasized the importance of electrification for broader investments in housing quality. For example, Tobey (1996, p.138-139) argues that “electrical modernization was not piecemeal; it led to the whole renovation of the home to bring the quality of living in it up to the electrical standard.” The initial spatial equilibrium will not be restored until these sunk investments are fully depreciated. Nevertheless, in the long-run the relative distribution of population across rural counties should eventually be restored to the pre-1930 equilibrium.²⁵

Alternatively, the short-term local advantage of early electrification may have persisted and even magnified in the post-1960 period, when electricity was universally adopted. This situation could arise if there were coordination problems, heterogeneous preferences over neighbor characteristics and local amenities, or strong economies of density (Duranton and Puga, 2004; Behrens and Robert-Nicoud, 2015). Early access to electricity may have helped resolve a residential coordination failure about where the co-locate (Bleakley and Lin, 2012). The expansion in rural electrification occurred during a period of high geographic mobility and rapid suburbanization.²⁶ The temporary local advantage may have concentrated mid-20th century suburbanization into specific rural counties. Assuming there were fixed costs associated with establishing new suburban communities, and provided that congestion costs were not too large, locations that electrified early could continue to attract suburban residents and experience persistent economic growth even after the country was fully electrified.

The mid-20th century geographic mobility featured an important demographic component, as predominantly white populations moved to suburban areas (Boustan, 2010).

²⁵This static model does not account for the long-run trends in rural-urban migration. The baseline prediction should be unaffected, however, since in the long-run, early and late electrifying rural counties should be affected similarly by this trend and thus should maintain stable relative populations.

²⁶In 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.

These preferences to sort across communities on the basis of socioeconomic characteristics such as a race and education levels may have reinforced the incentive to co-locate and ultimately determined the long-run spatial equilibrium (Behrens, Duranton, Robert-Nicoud, 2014; Behrens and Robert-Nicoud, 2015).²⁷ Moreover, if preferences for local amenities vary by socioeconomic status (Diamond, 2015), endogenous investment in local infrastructure could magnify the sorting response, as individuals select into communities on the basis of their desired levels of local amenity.²⁸

4 Data

Historical county-level data from 1930 to 2000 are drawn from the Censuses of Agriculture and Population (Haines and ICPSR, 2010; DOC and ICPSR, 2012). The main variables of interest include population (total, rural farm, rural non-farm, and urban); employment (total and by sector), 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 (FPC, 1963). These maps identify the location of all power plants in the U.S., along with various plant characteristics. To limit concerns of endogenous power plant siting, we restrict the sample to large power plants with at least 30 megawatts of nameplate capacity. Using GIS software, we digitize this information, and link it to historical information on the timing of plant openings to construct a panel of plants for the period 1930 to 1960. We combine these data with county longitude and latitude, to construct a decadal variable for county-centroid distance to the nearest power plant. The empirical analysis uses county-centroid distance to the nearest power plant as a measure of electricity access.²⁹

The main sample is a balanced panel of 2,162 counties that were at least 50 percent rural and within 200 miles of a power plant in 1930.³⁰ Figure A.4 displays the sample

²⁷There is growing evidence that temporary historical determinants can lead to persistent sorting across neighborhoods (see Lee and Lin, 2013; Heblich, Trew, and Zylberber, 2016).

²⁸There is a large literature documenting Tiebout sorting on the basis of local amenities such as public school quality (Black, 1999; Bayer, Ferreira, and McMillan, 2007), and environmental air quality (Banzhaf and Walsh, 2008; Heblich, Trew, and Zylberberg, 2016).

²⁹The identifying assumptions for the empirical analysis are discussed in Section 5.

³⁰We restrict the sample to counties within 200 miles of a power plant in 1930 to limit misspecification due to the fact that changes in distance will 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

counties shaded based on the change in distance to the nearest power plant between 1930 and 1960, with darker shades denoting larger decreases in distance.

5 Empirical Framework

We adopt two complementary empirical approaches to examine the short-run impact of rural electrification and the evolving long-run impact on the local economy. In both cases, our empirical strategy relies on cross-county differences in the timing of electricity access.

To study the immediate effects we adopt a generalized difference-in-differences approach with a continuous treatment à la Card (1992) or Acemoglu, Autor, and Lyle (2004)³¹, leveraging the openings of power plants between 1930 and 1960. Basically, we regress each outcome variable Y in county c and time t on distance to the nearest large power plant, $DistPP$, which is our continuous treatment variable, county fixed effects, η_c , and state-by-year fixed effects, λ_{st} . We also include a vector of baseline county characteristics (total population, fraction white, agricultural employment, and manufacturing employment, all measured in 1930, along with county-centroid latitude and longitude, an indicator for whether the county was located within 60 miles of an MSA in 1930, and total population, fraction white, and manufacturing employment in the nearest MSA in 1930), $X_{c,1930}$, interacted with year fixed effects. These covariates allow for differential trends in outcomes across counties according to these initial conditions.³² The estimating equation also includes an error term, ϵ_{ct} , and is given by

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

The variable $DistPP$ is measured in the negative of distance in tens of miles to reflect increases in electricity access. The coefficient β represents the (continuous) treatment effect of a 10 mile decrease in power plant distance. To understand why, consider the spatial distribution of power plants in 1930, and imagine new plants coming online in the 1930s. Rural counties initially far from any power plants, but facing a reduction in distance to a plant due to the openings, are defined as treatment counties. Because that reduction depends on county location relative to new plants, the intensity of the treatment varies continuously. Rural counties not experiencing changes in distance to

1930, and we drop an additional 306 counties for which data was missing on main outcomes variables.

³¹See discussion on Angrist and Pischke (2009), p.234-237.

³²Notice that we are controlling for the effect of a rural area being close to a “boom town” by allowing the trends in county outcomes to vary with initial conditions from the nearest MSA.

a power plant in the 1930s are defined as control counties. These can be counties relatively close to a plant by 1930, or counties too far from any plant in 1930 but still closer to a pre-1930 plant after the openings. Similarly, when new power plants come online in the 1940s or 1950s, some rural counties are treated and others are unaffected by the openings, thus acting as controls.

To study the longer term adjustments to rural electrification, we employ a difference-in-differences approach based on the timing of access to electricity, allowing the treatment effect to evolve over time. We define “early access” counties as those experiencing the majority of the reduction in distance to a power plant between 1930 and 1940, and “late access” counties as those experiencing the majority of the reduction between 1940 and 1960.³³ To identify the impact of large increases in electricity access, we restrict the sample to rural counties facing above-median decreases in power plant distance between 1930 to 1960, and compare relative changes in outcomes across early versus late access counties for the period 1960 to 2000.³⁴ Our difference-in-differences strategy should be straightforward here. “Early treatment areas” are rural counties affected by openings of power plants in the 1930s, and “late treatment areas” are rural counties affected by plants coming online in the 1940s and 1950s. Later on, we will provide evidence that those two groups of counties have similar pre-1930 trends for key outcome variables, appearing to be observationally comparable by 1930. 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, $X_{c,1930}$, interacted with year fixed effects³⁵, and an error term, ϵ_{ct} :

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

Notice that the treatment effects of early electricity access are allowed to vary by year. Each estimated coefficient β_t captures the average change in outcomes from 1930 to decade t for counties with early access relative to counties with late access to electricity, within the same state and trending similarly according to baseline observable characteristics.³⁶ Because both early and late access counties were fully electrified by 1960,

³³Qualitatively similar results, although less precisely estimated, are found when “late access” is calculated for the period 1950 to 1960 (reported in Table A.2, Panel A).

³⁴Similar estimates are found when the full sample of rural counties are included, and a triple difference strategy is pursued, using the counties with below-median decreases in distance to a power plant as an additional layer (see Table A.2, Panel B).

³⁵Again, note that we are controlling for the effect of a rural area being close to a “boom town” by allowing the trends in county outcomes to vary with initial conditions from the nearest MSA.

³⁶For 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

the estimates in equation (2) allow us to assess whether the timing of rural electrification had persistent effects on the local economy, where $\beta_t > 0$ implies amplification over time, $\beta_t < 0$ implies reversal, and $\beta_t = 0$ implies 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.³⁷

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.³⁸ This assumption is supported by three main pieces of evidence. First, the historical narrative that indicates 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 populated rural areas (Hughes, 1993; Casazza, 2004).³⁹

Second, given typical electricity consumption on the farm and in the home, and low rural population densities, rural demand accounted for only a small fraction of the total electricity produced by these large power plants. Among the power plants used in the empirical analysis, rural consumption accounted for less than 10 percent of total electricity generation. 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 of 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 1960.⁴⁰ We report these estimated differences separately

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).

³⁷Conley (1999) standard errors were also estimated for changes in key outcomes from 1930 to 1960 to allow for spatial correlation in the outcomes across counties. Conley standard errors were similar to the county-level standard errors. Relative to county-clustered standard errors, the increase in Conley standard errors for *DistPP* ranged from -4 to 23 percent for a 100-mile cutoff.

³⁸In practice, this assumption must hold only after controlling for differential trends according to geography, and baseline demographic and economic conditions of a county and its nearest MSA. The trends based on characteristics of the county's nearest MSA are included to control for potential concerns related to proximity to boom towns.

³⁹In fact, Morton (2000, p.29) notes that "private utilities insisted that extending service to these rural customers would be unprofitable." Moreover, at a cost of \$7,200 (1990 USD) per mile (Beall, 1940), it was far cheaper to extend rural lines than to build power plants to meet rural demand.

⁴⁰Notice that this test of baseline characteristics in levels is more stringent than the identifying assumption that rural counties would have trended similarly in the absence of rural electrification.

for rural counties that gained early access (column 2) and late access (column 3). Panel A shows that future expansions in electricity access were generally unrelated to baseline farm outcomes. Counties that experienced large decreases in power plant distance tended to have larger average farm size, consistent with expansion of the power grid into less densely populated areas. Panel B reports baseline differences in rural population and employment characteristics. Again, there were few systematic differences across rural counties according to the magnitude of future decreases in power plant distance. If anything, counties that experienced large decreases in distance were somewhat less populous, had less manufacturing employment, and were more non-white. 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 $\theta_t X_{c,1930}$ covariates allow rural counties to trend differentially according to observable baseline conditions, including those of each county’s nearest MSA.

6 Results

6.1 Short-Run Effects of Rural Electrification

6.1.1 Effects on population, employment, and farm output

Table 2 reports estimates of the direct effect of rural electricity access on the rural sector. Columns (2)-(6) report coefficients of $DistPP$ estimated by equation (1) across several different specifications. Column (2) includes county and year fixed effects and a linear state trend to allow for different long-run trends across states; in column (3) we add controls for county longitude, latitude, and proximity to MSAs interacted with year, to allow for differential trends based on geography; in column (4) we add controls for baseline demographic and economic characteristics interacted with year fixed effects; in column (5) we add similar baseline demographic and economic characteristics from the nearest MSA interacted with year fixed effects to control for boom town dynamics; and in column (6), we replace the state trend with state-by-year fixed effects.

Panel A reports the estimates for rural population and agricultural employment. Across a range of specifications, access to electricity is associated with significant increases in farm population and agricultural employment. The preferred estimates imply that a one standard deviation increase in electricity access is associated with a 1.3 percent increase in rural farm population and a 3.5 percent increase in agricultural em-

ployment. These results suggest that electrification slowed the pace of rural population decline. In sample counties, over four and a half million workers left the agricultural sector between 1930 and 1960. Had electricity infrastructure remained at the 1930 level, an additional 200,000 workers would have left the sector.

Panel B reports estimates for agricultural output. The results suggest that electricity access led to an expansion in agricultural output. Decreases in power plant distance are associated with significant increases in farm revenue. This increase in farm output was driven both by a response on the extensive margin – electricity access led to increases in the number of farms and total county land devoted to agriculture –, and a response on the intensive margin – electricity access is associated with increases in average farm size and greater adoption of tractors. These results 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 support broad local economic development through positive productivity spillovers and/or increased demand for locally-traded goods, or it could crowd-out non-agricultural production. To explore this question, Table 3 reports the broader effects of rural electrification on the local economy. Panel A shows that expansions in rural electricity access had little impact on total county population. Similarly, we find that the relative expansion in agricultural employment is roughly offset by a decline in manufacturing employment, leaving overall employment unchanged. Panel C reports the effects of rural electrification on socioeconomic characteristics of the local population. There is no evidence that rural electrification influenced the pattern of migration in the short-run. Key indicators of the composition of the local population (fraction white, fraction with a high school diploma, and retail spending) are unrelated to changes in electricity access. Together these results suggest that, in the short-run, rural electrification slowed the pace of within-county rural-urban migration, but had little impact on cross-county migration.

6.1.2 Effects on property values and income

The expansion in the rural sector could have been driven by improvements in rural housing quality that slowed the pace of rural outmigration, or increased demand for rural labor driven by productivity advances on the farm. To shed light on the mechanisms, Table 4 reports the effects of rural electrification on property values and

income. Expansions in electricity access led to increases in local property values, as measured by farm values, median dwelling values, and median dwelling rents.⁴¹ The point estimates are all statistically significant at conventional levels, and imply that a one standard deviation increase in electricity access raised rural property values by approximately two percent. On the other hand, rural electrification did not influence local wages, as measured by farm, retail, or manufacturing payroll per worker.

The large increases in property values and limited response in wages are consistent with a setting in which rural electrification brought benefits to rural residents through both increases in agricultural productivity and improvements in the quality of rural housing. These patterns are consistent with the Rosen-Roback framework in which a change in local electricity access leads to a shift in both the rural worker’s indirect utility curve and the rural producer’s cost curve (see Figure A.3). In fact, these reduced form estimates can be applied to calculate the aggregate benefit of electricity to the rural sector, and the fraction accruing to rural residents and rural producers (see model details in Appendix A.2). 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:

$$p_e^*N^R + [-C_eX^R] = \frac{d \log q}{de} \cdot L^R \cdot q, \quad (3)$$

where q denotes the annual value of an acre of farmland, L^R denotes the total number of acres used for farming in the county, and $\frac{d \log q}{de}$ denotes the impact of a change in electricity access on the logarithm of farmland values.

We combine the estimated impact of electricity access on farmland values (Table 4, col. 6) with sample means of q and L^R to calculate the rural willingness-to-pay for electricity. To derive an explicit measure of de , we rescale the effects by the impact of power plant distance on the fraction of farm households with electricity, $\frac{de}{dDistPP} = 0.0015$ (S.E. 0.0007). We also rescale our calculations to reflect the rural benefits of an increase in the average proportion of farms with electrical services from less than 0.15 in 1930 to nearly universal access in 1960.⁴² These estimates are combined with sample

⁴¹Separate data on the values of agricultural land and buildings is not consistently available throughout the sample period. When these data are separately available, land accounts for the vast majority of total farm value.

⁴²These willingness-to-pay calculations might overestimate the benefits of farm electrification if power plant distance affected agricultural productivity independently of farm household electrification. For example, if increased access to electricity infrastructure spurred investment in other local infrastructure.

means for total acres in farming, $L^R = 306,245$, and the mean annual value of an acre of farmland, $q = \$11.35$.⁴³ We calculate the following annual aggregate willingness-to-pay for both the productivity and amenity benefits of increased electricity access: $0.85 \times (p_e^* N^R + [-C_e X^R]) = 0.85 \times ([0.0045/0.0015] \times 11.35 \times 306,245) = \$8,863,496$ per county. This estimate implies that a typical farm household would have been willing to forgo 46 percent of annual income to gain access to electricity.⁴⁴

We evaluate the extent to which the benefits associated with increased electrification were due to productivity gains or improvements in household amenities. The sum of the amenities to rural workers can be expressed as follows:

$$p_e^* N^R = \left(k_l \cdot \frac{d \log q}{de} - \frac{d \log w}{de} \right) \cdot w \cdot N^R \quad (4)$$

where k_l denotes the fraction of the household's annual budget spent on residential land, which we set equal to 0.18 based on the fraction of household income spent on rent in the sample in 1950. The term w is annual rural wages, which we calculate to be \$4,393.⁴⁵ The term $\frac{d \log w}{de}$ is the impact of electrification on local wages, which we set equal to zero given the insignificant wage effects reported in Table 4. The value associated with improved household amenities is given by: $0.85 \times (p_e^* N^R) = 0.85 \times (0.18 \times [0.0045/0.0015] \times 4,393 \times 2,606) = \$5,254,704$. The estimates imply that rural residents would have been willing to forgo 27 percent of annual revenue to reside in an electrified home.⁴⁶ Therefore, almost 60 percent of the benefits from increased rural electrification occurred through non-market amenities rather than improvements in agricultural production.

Given the large benefits associated with rural electrification, it might seem surprising that individual farms did not electrify themselves. Small diesel generators were

⁴³Following Fogel (1964) and Donaldson and Hornbeck (2016), we use mortgage interest rates to convert agricultural land values to an annual economic value. The interest rates charged on land bank loans over the period 1933-1954 were between 3.5 and 4.5 percent (Saulnier, Halcrow, and Jacoby, 1958), so we use 4 percent in our calculations (average value of an acre of farmland $\times 0.04 = \$283.77 \times 0.04 = \11.35). All dollar amounts are reported in 1990 USD.

⁴⁴To obtain this proportion, we proceed in two steps. First, we divide the total gains per county by the average number of farms to get the average gains per farm, that is, $\$8,863,496/1,937 = \$4,576$. Then, we divide the quotient from the first step by the average farming revenue per farm ($\$19,071,190/1,937 = \$9,846$), that is, $\$4,576/\$9,846 = 0.46$.

⁴⁵The rural wage derived assuming a 0.6 labor share in agriculture (Herrendorf and Valentinyi, 2008).

⁴⁶Again, to obtain this proportion, we proceed in two steps. First, we divide the amenity gains per county by the average number of farms to get the average gains per farm, that is, $\$5,254,704/1,937 = \$2,713$. Then, we divide the quotient from the first step by the average farming revenue per farm: $\$2,713/\$9,846 = 0.27$.

available to meet electricity demands for customers who could not easily connect to the grid, and in the early 20th century, a number of small isolated municipalities and individual industrial plants relied on them to produce their own power. Nevertheless, less than four percent of farms used home generations in 1930, and these were typically used only to meet basic household needs, such as lighting. The standard 1-kilowatt diesel generator that was typically purchased by farm households cost between \$2,300 and \$5,200, and the monthly operating costs could run from \$45 to \$450 (Nye, 1990). These costs would have been prohibitively expensive for the overwhelming majority of farmers.⁴⁷ On the other hand, the historical cost of extending the grid ranged from \$13,500 to \$16,000 per mile in the early 1930s, and quickly fell to \$7,200 under the REA (Beall, 1940). Even at population densities of only 2 or 3 farms per mile, these line extensions could have been easily justified based on the value of this technology for the rural population.

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. These models allow for differential trends in rural outcomes according to these baseline conditions. In practice, the covariates have little impact on the main results.

Columns (3) - (6) explore the sensitivity of the results to alternative samples. In column (3), we exclude counties located within 30 miles of a power plant. This sample restriction addresses concerns that power plants were sited in response to changes in rural demand for electricity. This restriction also addresses concerns related to emissions from coal-fired power plants. In particular, pollution from electricity generation has been shown to have negative effects on local property values (Clay, Lewis, and Severini, 2016). In column (4) we drop counties west of the 100th meridian to address the concern that county-centroid distance to the nearest power plant is a noisier measure of electricity access in larger western counties. 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

⁴⁷Nye (1990, p.295) argues that less than one in twenty farms could afford to purchase a generator.

outcomes independently of electrification (Kitchens, 2014; Kline and Moretti, 2014). Although sometimes less precisely estimated, the results do not appear too sensitive to these various sample restrictions.

In the final two columns, we further address concerns related to the endogenous siting of power plants. In column (7), we re-estimated the baseline model using only power plants with at least 50 MW of nameplate capacity. Locational choices for these large plants is highly unlikely to have been influenced by rural demand for power. The estimates in column (8) rely solely on variation in county distance to private power plants. Because private utilities were less interested in servicing high cost rural customers, the siting of these power plants should not have been influenced by the characteristics of the rural population. The main findings are qualitatively similar in both models.

6.2 Long-Run Effects of Rural Electrification

6.2.1 Estimated local impacts of early electricity access

Next, we examine the long-run adjustments to rural electrification. To motivate our empirical strategy, and assess the validity of the common trends assumption, Figure 3 plots the estimated β 's 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 2000.⁴⁸ Panel A graphs the estimates for population and employment, panel B graphs the effects for property values and income, and panel C graphs the estimates for rural outcomes.

We find little evidence of pre-trends across early and late electricity access counties. The estimated β 's are small and generally insignificant prior to 1930, supporting the research design. Nevertheless, these two groups of counties experienced markedly different trends post-1960. Early electricity access counties experienced large and persistent growth in population and employment in the post-1960 period. Over time, these counties also experienced substantial relative increases in property values and modest increases in worker incomes. This expansion does not appear to have been driven by the rural sector. Early electricity access counties experienced relative decreases in rural population, agricultural employment, and total land in farming from 1960 and 2000.

Table 6 reports the estimates of β for the post-1960 period. Panel A reports the effects for population and employment. Early access counties experienced relative pop-

⁴⁸Because equation (2) controls for the outcome variable in 1930, these changes are estimated relative to 1930.

ulation and employment growth in each decade between 1960 and 2000. By 2000, these counties were 15 percent more populous relative to late access counties. The last four columns report the estimates for sectoral employment. Employment growth was not driven by the agricultural sector. In 1960, relative agricultural employment decreased by 9 percent in early electrifying counties, suggesting a reversal of the short-run effects. Instead, employment growth was concentrated in non-traded sectors, and by 2000, relative employment in retail and construction was over 22 percent higher in early electricity access counties.

Panel B reports the results for property values and local incomes. Over time, counties that gained early access to electricity experienced increases in local property values, and by 1990, median dwelling values were 10 percent higher than in observationally equivalent late electrifying counties. Early electrification also led to relative increases in local wages, as measured by retail payroll per worker and manufacturing payroll per worker. Given the possibility of long-run worker sorting (see Table 8), the homogeneity assumption underlying the standard Rosen-Roback framework is unlikely to hold, and relative impacts on local property values and incomes cannot be directly compared to estimate the long-run welfare benefits associated with early electrification.

Panel C reports the results for rural outcomes. There is no evidence that population growth in early electrifying counties was driven by a long-term expansion of the agricultural sector. Instead, early electrification led to relative decreases in total farm population and farmland. Early electrifying counties experienced a temporary relative increase in farm revenue per worker, which could have been driven by slow-moving investment adjustments in the agricultural sector. Overall, it appears that the relative expansion in the agricultural sector was a short-term phenomenon that was reversed within 30 years.

Together, the results in Table 6 suggest that the timing of rural electrification had persistent impacts on local economic activity. Rural counties that gained early access to electricity experienced a long-run expansion in population, property values, and incomes, relative to late access rural counties in the same state that trended similarly on observable characteristics. The results further show that these effects were driven by expansion that occurred outside of the agricultural sector, suggesting that early electrification was a catalyst from broad-based local development. These main findings are robust to several alternative specifications. In Panel A of Table A.2, we redefine late access rural counties as those that experienced the majority of the reduction in distance between 1950 and 1960. The key results remain largely unchanged, though sometimes less precisely estimated. In Panel B, we report the estimates for the full sample of 2,162

rural counties used in the short-run analysis in a triple-difference strategy, in which early electricity access is interacted with an indicator for counties that experienced above-median decreases in distance between 1930 and 1960. These difference-in-differences coefficients display the same qualitative pattern in the 1960-2000 period.

6.2.2 Rural electrification and patterns of local development

Differences in the timing of electricity access led to a cross-county divergence in outcomes that persisted 40 years after the country was fully electrified. Recent research in economic geography has shown that a temporary shock can permanently alter the location of economic activity (e.g., Bleakley and Lin, 2012; Kline and Moretti, 2014; Severnini, 2014). This situation is more likely to arise in settings with increasing returns to density and fixed costs of relocation. In this case, a temporary local advantage, such as early access to electricity, can continue to attract individuals and investments even after the local advantage has been eliminated. The temporary local advantage can serve as a coordination mechanism in the selection of a spatial equilibrium, particularly when workers have preferences to co-locate according to socioeconomic characteristics such as race and education.

The mid-20th century was a period of high population mobility and significant residential sorting (Baum-Snow, 2007; Boustan, 2010) in which the temporary local advantage of electricity access was particularly likely to influence long-term economic outcomes through suburban expansion. Indeed, historians have identified the role of rural electrification in suburban growth. For example, Nye (1993, p.25) argues that “rural electrification both improved farm life and helped depopulate the farms... with the decline of farm membership and the rise of suburban areas within its jurisdiction.” On the other hand, because rural electrification seems to have enhanced productivity and amenities in the countryside, it is possible that rural counties distant from urban areas might have followed a different pattern of local development driven by improvements in the rural sector.

To evaluate the role of rural electrification in mid-20th century local economic growth, we re-estimate a 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. Intuitively, these models allow for the effects of early electricity access to differ across counties that were more or less likely to be destinations for suburbanization.⁴⁹

⁴⁹Given 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

Tables 7 and 8 report the estimated effects of early access across rural counties near and far from MSAs.⁵⁰ The results suggest that the long-term economic local effects of early access were related to either mid-20th century suburbanization or improvements in agriculture. Irrespective of MSA distance, long-run population, employment, retail and construction activity, farmland values, and proxies for income increased in early electrifying counties. Nevertheless, in rural counties located near MSAs, early access led to large decreases in farmland and farm population, and increases in the percentage of high-school graduates and housing prices, suggesting expansions in the suburban sprawl that crowded-out agriculture production, and sorting of more educated workers around MSAs. In rural counties far from MSAs, however, early access led to increases in farm productivity (measured by farm revenue per worker) and farm population, consistent with a pattern of development centered in the rural sector. Complementarities with agricultural production (or better rural amenities) might have attracted people to these counties, making them a focal point for development. This long-run expansion in the agricultural sector may have been driven by either the gradual adoption of complementary agricultural technologies (e.g. Assuncao, Lipscomb, Mobarak, and Szerman, 2016) or long-term adjustments in the quality of land used in agriculture.

It is important to point out that the positive effects on local incomes in early electrifying counties near MSAs (Table 8, cols. 1-3) could reflect either long-term productivity effects or changes in the composition of the workforce driven by worker sorting. In fact, columns (4) and (5) show that early access led to increases in the fraction of whites and increases in fraction of the adult population with a high school degree only in near-MSA counties. These changes coincide with previous evidence on the demographics of the rising suburban population (Boustan, 2010), and suggest that the incentive to co-locate on the basis of race and education reinforced the population response to early electrification in locations close to MSAs. Table 8 also provides evidence that early electricity access stimulated greater investment in local amenities independently of MSA distance, as measured by the fraction of new housing starts, and growth in construction and retail employment.⁵¹

estimates, are found when these controls are included (available upon request).

⁵⁰Because we lack information on county income, the fraction of houses built within the previous decade, and the fraction of adults with a high school diploma in the year 1930, the estimates reported in columns (3), (5), and (6) are not estimated relative to baseline outcomes in 1930, $Y_{c,1930}$, although they do include the rest of the controls reported in equation (2).

⁵¹Diamond (2015) also finds evidence of endogenous amenity investments driven by cross-city differences in the socioeconomic composition of the population. However, Hornbeck and Keskin (2015) find that agriculture does not appear to generate economic spillovers on local nonagricultural activity in the areas over the Ogallala aquifer that experienced agricultural gains due to access to groundwater.

Early electricity access appears to have played a significant role in suburban growth during the second half of the 20th century. We assess the sensitivity of these results to another source of suburban growth: the mid-20th century construction of the interstate highway system (Baum-Snow, 2007). In particular, we re-estimate equation (2), including controls for a dummy variable indicating whether the 1944 planned interstate route intersected the rural county (Michaels, 2008) interacted with year fixed effects.⁵² Table A.3 reports these results. The bottom panel reports the estimates for the planned interstate. The estimates suggest that highway construction led to increases in population and employment, but had little impact on local property values or farm outcomes. Importantly, the inclusion of these covariates has little impact on the main estimates. Together the estimates suggest that both transportation and electricity infrastructure had independent effects on long-run population growth in these rural counties.

7 Conclusion

This paper exploited the historical rollout of the U.S. power grid between 1930 and 1960 to study the evolving impact of rural electrification on local economies. Our empirical analysis provided evidence that rural electrification led to short-run increases in agricultural employment, farm population, and property values, but had limited impacts on nonagricultural sectors. The short-run local benefits were driven by both improvements in agricultural productivity and non-market amenities associated with improved rural housing, and were estimated to have exceeded the historical cost of extending the grid, even at low population densities.

In addition to these short-run effects, rural counties that gained early access to electricity experienced long-run economic growth that persisted long after the country was fully electrified. In rural counties located near metropolitan areas, this long-run expansion was concentrated in nonagricultural sectors, and was reinforced by worker sorting. The results suggest that early electrification helped resolve a coordination problem during mid-20th century suburbanization, which ultimately influenced the long-run spatial distribution of economic activity. In more remote rural counties, however, the long-run growth seemed to be driven by improvements in the rural sector. Complementarities with agricultural production or better rural amenities may have attracted population, making those counties a focal point for development. Taken together, the findings show how gradual local adjustments to rural electrification can either reinforce or re-

⁵²Because early electrification may have influenced future investment in transportation infrastructure, we do not directly control for the actual highway network.

verse short-run effects, and highlight the importance of accounting for these long-run responses when making electricity infrastructure investment decisions.

Our findings have relevance for current policy in the developing world. Recent evidence from Kenya, for instance, suggests that even in rural communities with high population density, electrification rates remain very low, and households appear to be unable or unwilling to pay the connection cost individually (Lee et al., 2016). Our willingness-to-pay estimates suggest that credit constraint might be a key barrier, and that government loans or subsidies for rural electrification to rural populations may offer large welfare gains. This situation is analogous to the historical U.S., where substantial government interventions were necessary to provide electricity access to the more rural parts of the country. Our findings also suggest that investment in rural electrification may be a key catalyst for suburban growth. To the extent that policy-makers in developing countries seek to accelerate the pace of the rural-urban transition, increased investment in electric grid infrastructure help achieve this objective.

References

- Acemoglu, Daron. (2010). "When Does Labor Scarcity Encourage Innovation?" *Journal of Political Economy* 118(6): 1037-1078.
- Acemoglu, Daron, David H. Autor, and David Lyle. (2004). "Women, War, and Wages: The Effect of Female Labor Supply on the Wage Structure at Midcentury," *Journal of Political Economy* 112(3): 497-551.
- Angrist, Joshua D., and Jorn-Steffen Pischke. (2009). *Mostly Harmless Econometrics: An Empiricist's Companion*. Princeton, NJ: Princeton University Press.
- Assuncao, Juliano, Molly Lipscomb, A. Mushfiq Mobarak, and Dimitri Szerman. (2016). "Agricultural Productivity and Deforestation in Brazil," *Mimeo*.
- Atack, Jeremy, Fred Bateman, Michael Haines, and Robert A. Margo. (2010). "Did Railroads Induce or Follow Economic Growth? Urbanization and Population Growth in the American Midwest, 1850-1860," *Social Science History* 34: 171-197.
- Atack, Jeremy, and Robert A. Margo. (2011). "The Impact of Access to Rail Transportation on Agricultural Improvement: The American Midwest as a Test Case, 1850-1860," *Journal of Transport and Land Use* 4: 5-18.
- Banerjee, Abhijit, Esther Duflo, and Nancy Qian. (2012). "On the Road: Access to Transportation Infrastructure and Economic Growth in China," *NBER Working Paper #17897*.

- Banzhaf, H. Spencer, and Randall P. Walsh. (2008). "Do People Vote with Their Feet? An Empirical Test of Tiebout's Mechanism," *American Economic Review* 98(3): 843-863.
- Baum-Snow, Nathaniel. (2007). "Did Highways Cause Suburbanization?" *Quarterly Journal of Economics* 122(2): 775-805.
- Bayer, Patrick, Fernando Ferreira, and Robert McMillan. (2007). "A Unified Framework for Measuring Preferences for Schools and Neighborhoods," *Journal of Political Economy* 115(4): 588-638.
- Beall, Robert T. (1940). "Rural Electrification," *Yearbook of Agriculture*: 790-809.
- Behrens, Kristian, Gilles Duranton, and Frederic Robert-Nicoud. (2014). "Productive Cities: Sorting, Selection, and Agglomeration", *Journal of Political Economy* 122(3): 507-553.
- Behrens, Kristian, and Frederic Robert-Nicoud. (2015). "Agglomeration Theory with Heterogeneous Agents". In: Gilles Duranton, J. Vernon Henderson and William C. Strange (eds.) *Handbook of Regional and Urban Economics*, vol. 5, chapter 4, Elsevier: North-Holland, pp. 171-245.
- Black, Sandra E. (1999). "Do Better Schools Matter? Parental Valuation of Elementary Education," *Quarterly Journal of Economics* 114(2): 577-599.
- Bleakley, Hoyt, and Jeffrey Lin. (2012). "Portage and Path Dependence", *Quarterly Journal of Economics* 127(2): 587-644.
- Boustan, Leah Platt. (2010). "Was Postwar Suburbanization 'White Flight'? Evidence from the Black Migration," *Quarterly Journal of Economics* 125(1): 417-443.
- Burlig, Fiona, and Louis Preonas. (2016). "Out of the Darkness and Into the Light? Development Effects of Rural Electrification," *Mimeo*.
- Card, David. (1992). "Using Regional Variation in Wages to Measure the Effects of the Federal Minimum Wage," *Industrial and Labor Relations Review* 46(1): 22-37.
- Chakravorty, Ujjayant, Martino Pelli, and Beyza Ural Marchand. (2014). "Does the Quality of Electricity Matter? Evidence from Rural India," *Journal of Economic Behavior & Organization* 107(A): 228-247.
- Chakravorty, Ujjayant, Kyle Emerick, and Majah Leah-Ravago. (2016). "Lighting Up the Last Mile: The Benefits and Costs of Extending Electricity to the Rural Poor," *Mimeo*.
- Clay, Karen, Joshua Lewis, and Edson Severnini. (2016). "Canary in a Coal Mine: Infant Mortality, Property Values, and Tradeoffs Associated with Mid-20th Century Air Pollution", *NBER Working Paper #22155*.

- Conley, Timothy G. (1999). "GMM Estimation with Cross-Sectional Dependence," *Journal of Econometrics* 92(1): 1-45.
- Coppock, Joseph D. (1940). *Government Agencies of Consumer Instalment Credit*, NBER Books.
- Cowan, Ruth Schwartz. (1976). "The 'Industrial Revolution' in the Home: Household Technology and Social Change in the 20th Century", *Technology and Culture* 17(1): 1-23.
- David, Paul A. (1990). "The Dynamo and the Computer: An Historical Perspective on the Modern Productivity Paradox", *American Economic Review: Papers and Proceedings* 80(2):355-361.
- Davis, Donald R., and David E. Weinstein. (2002). "Bones, Bombs, and Break Points: The Geography of Economic Activity," *American Economic Review* 92(5): 1269-1289.
- Devine, Warren D. (1983). "From Shafts to Wires: Historical Perspective on Electrification," *Journal of Economic History* 43(2): 347-372.
- Diamond, Rebecca. (2016). "The Determinants and Welfare Implications of US Workers' Diverging Location Choices by Skill: 1980-2000", *American Economic Review* 106(3): 479-524.
- Dinkelman, Taryn. (2011). "The Effects of Rural Electrification on Employment: New Evidence from South Africa," *American Economic Review* 101(7): 3078-3108.
- Dinkelman, Taryn, and Sam Schulhofer-Wohl. (2015). "Migration, Congestion Externalities, and the Evaluation of Spatial Investments," *Journal of Development Economics* 114(1): 189-202.
- Donaldson, Dave. (2013). "Railroads of the Raj: Estimating the Impact of Transportation Infrastructure," *American Economic Review*.
- Donaldson, Dave, and Richard Hornbeck. (2016). "Railroads and American Economic Growth: A 'Market Access' Approach", *Quarterly Journal of Economics* 131(2): 799-858.
- Duflo, Esther, and Rohini Pande. (2007). "Dams," *Quarterly Journal of Economics* 122(2): 601-646.
- Duranton, Gilles, and Diego Puga. (2004). "Micro-Foundations of Urban Agglomeration Economies". In: J. Vernon Henderson and Jacques-Francois Thisse (eds.) *Handbook of Regional and Urban Economics*, vol. 4, chapter 48, Elsevier: North-Holland, pp. 2063-2117.
- Duranton, Giles, Peter M. Morrow, and Matthew A. Turner. (2014). "Roads and Trade: Evidence from the US", *Review of Economic Studies* 81(2): 681-724.

Electrical World, March 1938.

Faber, Benjamin. (2014). “Trade Integration, Market Size, and Industrialization: Evidence from China’s National Trunk Highway System”, *Review of Economic Studies* 81(3): 1046-1070.

Fishback, Price, and Carl Kitchens. (2015). “Flip the Switch: The Impact of the Rural Electrification Administration 1935-1940,” *Journal of Economic History* 75(4): 1161-1195.

Fogel, Robert W. (1964). *Railroads and American Economic Growth: Essays in Econometric History*. Baltimore, MD: Johns Hopkins University Press.

General Electric Digest, April 1925.

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

Haines, Michael, and Robert A. Margo. (2008). “Railroads and Local Development: The United States in the 1850s,” in *Quantitative Economic History: The Good of Counting*, J. Rosenbloom, ed. (London: Routledge), 78-99.

Heblich, Stephan, Alex Trew, and Yanos Zylberberg. (2016). “East Side Story: Historical Pollution and Persistent Neighborhood Sorting,” *Mimeo*.

Herrendorf, Berthold, and Akos Valentinyi. (2008). “Measuring Factor Income Shares at the Sector Level,” *Review of Economic Dynamics* 11: 820-835.

Hornbeck, Richard. (2012). “The Enduring Impact of the American Dust Bowl: Short- and Long-Run Adjustments to Environmental Catastrophe,” *American Economic Review* 102(4): 1477-1507.

Hornbeck, Richard, and Pinar Keskin. (2015). “Does Agriculture Generate Local Economic Spillovers? Short-Run and Long-Run Evidence from the Ogallala Aquifer,” *American Economic Journal: Economic Policy* 7(2): 192-213.

Hughes, Thomas. (1993). *Networks of Power: Electrification in Western Society, 1880-1930*. Baltimore, MD: Johns Hopkins University Press.

International Energy Agency (IEA). (2016). *World Energy Outlook*, available at worldenergyoutlook.org/publications/weo-2016/.

Kitchens, Carl. (2014). “The Role of Publicly Provided Electricity in Economic Development: The Experience of the Tennessee Valley Authority,” *Journal of Economic History* 74(2): 389-419.

- Kline, Patrick, and Enrico Moretti. (2014). "Local Economic Development, Agglomeration Economies, and the Big Push: 100 Years of Evidence from the Tennessee Valley Authority," *Quarterly Journal of Economics* 129(1): 275-331.
- Lebergott, Stanley. (1976). *The American Economy: Income, Wealth and Want*. Princeton NJ: Princeton University Press.
- Lee, Kenneth, Eric Brewer, Carson Christiano, Francis Meyo, Edward Miguel, Matthew Podolsky, Javier Rosa, Catherine Wolfram. (2016). "Electrification for 'Under Grid' Households in Rural Kenya," *Development Engineering* 1: 26-35.
- Lee, Kenneth, Edward Miguel, and Catherine Wolfram. (2016). "Experimental Evidence on the Demand for and Costs of Rural Electrification," *Mimeo*.
- Lee, Sanghoon and Jeffrey Lin. (2013). "Natural Amenities, Neighborhood Dynamics and Persistence in the Spatial Distribution of Income," *Federal Reserve Bank of Philadelphia Working Paper*.
- Lewis, Joshua. (2016a). "Short-run and Long-run Effects of Household Electrification," *Mimeo*.
- Lewis, Joshua. (2016b). "Fertility, Child Health, and the Diffusion of Electricity into the Home," *Mimeo*.
- Lipscomb, Molly, A. Mushfiq Mobarak, and Tania Barham. (2013). "Development Effects of Electrification: Evidence from the Topographic Placement of Hydropower Plants in Brazil," *American Economic Journal: Applied Economics* 5(2): 200-231.
- Michaels, Guy. (2008). "The Effect of Trade on the Demand for Skill: Evidence from the Interstate Highway System," *Review of Economics and Statistics* 90(4): 683-701.
- Morton, David. (2000). *Power: A Survey History of Electric Power Technology Since 1945*. New York: IEEE Press.
- Murphy, Kevin M., Andrei Shleifer, and Robert W. Vishny. (1989). "Industrialization and the Big Push," *Journal of Political Economy* 97(5): 1003-1026.
- National Electric Light Association (NELA). (1925). *Proceedings, 48th Convention*.
- Nye, David E. (1990). *Electrifying America: Social Meanings of a New Technology: 1880-1940*. Cambridge, MA: The MIT Press.
- Olmstead, Alan, and Paul Rhode. (2001). "Reshaping the landscape: the impact and diffusion of the tractor in American agriculture, 1910-1960," *Journal of Economic History* 61(3): 663-698.
- Ramey, Valerie A. (2009). "Time Spent in Home Production in the Twentieth-Century United States: New Estimates from Old Data," *Journal of Economic History* 69(1): 1-47.

- Redding, Stephen J., and Daniel M. Sturm. (2008). "The Costs of Remoteness: Evidence from German Division and Reunification," *American Economic Review* 98(5): 1766-97.
- Roback, Jennifer. (1982). "Wages, Rents, and the Quality of Life," *Journal of Political Economy* 90(6): 1257-1278.
- Rosen, Sherwin. (1979). "Wages-Based Indexes of Urban Quality of Life. In *Current Issues in Urban Economics*, edited by Peter Mieszkowski and Mahlon Straszheim, 74-104. Baltimore: John Hopkins University Press.
- Rosenstein-Rodan, Paul N. (1961). "Notes on the Theory of the 'Big Push'. In *Economic Development for Latin America*, edited by Howard S. Ellis and Henry C. Wallich. New York: St. Martin's, 57-81.
- Rostow, Walt W. (1960). *The Stages of Economic Growth: A Non-Communist Manifesto*. Cambridge: Cambridge University Press.
- Ryan, Nicholas. (2014). "The Competitive Effects of Transmission Infrastructure in the Indian Electricity Market," *Mimeo*.
- Saulnier, Raymond J., Harold G. Halcrow, and Neil H. Jacoby. (1958). *Federal Lending and Loan Insurance*. Princeton, NJ: Princeton University Press.
- Severnini, Edson. (2014). "The Power of Hydroelectric Dams: Agglomeration Spillovers," *IZA Discussion Paper #8082*.
- Steckel, Richard, and William White. (2012). "Engines of Growth: Farm Tractors and Twentieth-Century U.S. Economic Welfare," *NBER Working Paper #17879*.
- Stewart, E.A., J.M. Larson, and J. Romness. (1927). *The Red Wing Project on Utilization of Electricity in Agriculture*. University of Minnesota Agricultural Experiment Station, Division of Agricultural Engineering.
- Strobl, Eric, and Robert O. Strobl. (2011). "The Distributional Impact of Large Dams: Evidence from Cropland Productivity in Africa", *Journal of Development Economics* 96(2): 432-450.
- Tobey, Ronald C. (1996). *Technology as Freedom: The New Deal and the Electrical Modernization of the American Home*. Berkeley, CA: University of California Press.
- U.S. Census Bureau. (1976). *Historical Statistics of the United States, Colonial times to present*. Washington D.C.: U.S. Census Bureau.
- U.S. Department of Agriculture (USDA). (1944). *The Time Costs of Homemaking – A Study of 1,500 Rural and Urban Households*. Agricultural Research Administration, Bureau of Human Nutrition and Home Economics.

U.S. Department of Agriculture (USDA). (1997). *Usual Planting and Harvesting Dates for U.S. Field Crops*. Washington D.C.: USDA.

U.S. Department of Commerce, Bureau of the Census. (1943). *Sixteenth Census of the United States: 1940. Housing, Volume II: General Characteristics*. Washington, DC: Government Printing Office.

U.S. Department of Commerce, Bureau of the Census. (1953). *Census of Housing, 1950. Volume I: General Characteristics*. Washington, DC: Government Printing Office.

U.S. Department of Commerce, Bureau of the Census. (1963). *Census of Housing, 1960. Volume I: States and Small Areas*. Washington, DC: Government Printing Office.

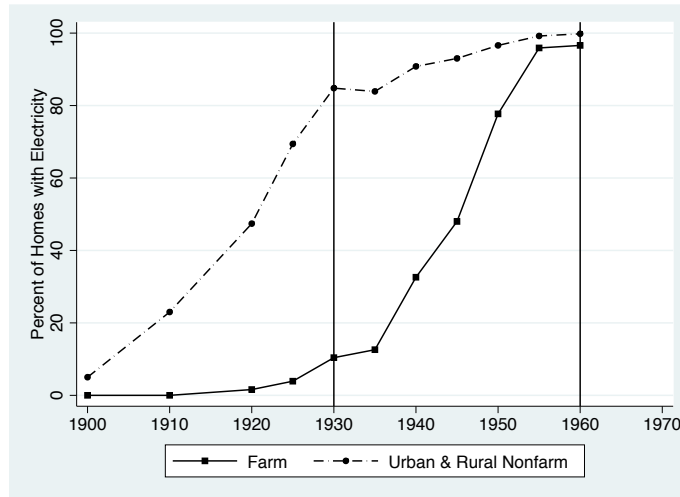
U.S. Department of Commerce (DOC), Bureau of the Census, and Inter-university Consortium for Political and Social Research (ICPSR). (2012). *County and City Data Book (United States) Consolidated File: County Data, 1947-1977*. Ann Arbor, MI: Inter-university Consortium for Political and Social Research, icpsr.org.

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

Wilson, Maud. (193-). *Present Use of Time in Households and by Homemakers: Complete Report of Purnell Study*, Oregon State Agricultural Experiment Station.

8 Figures and Tables

Figure 1: % farm and nonfarm households with electricity



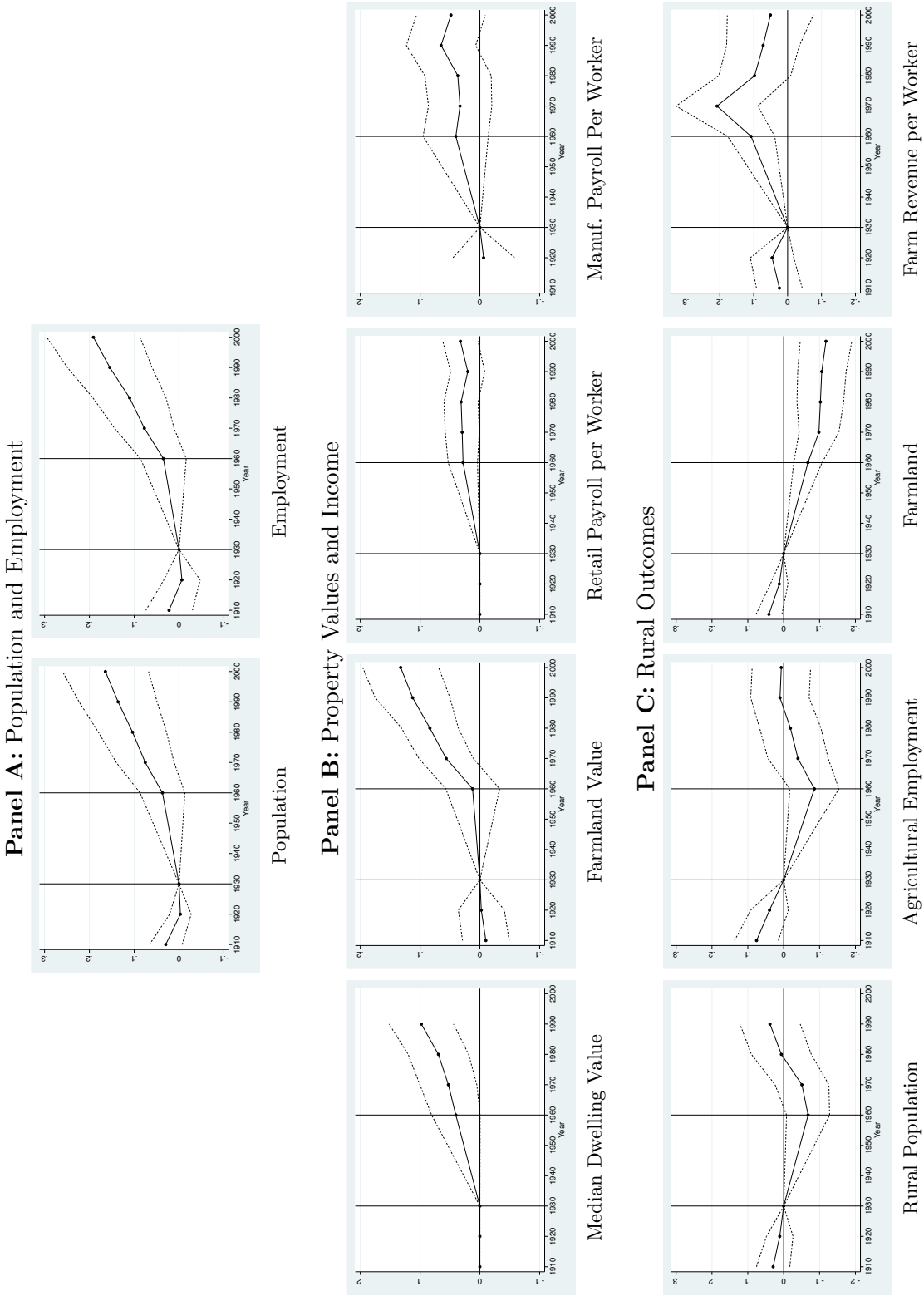
Source: Lebergott (1976, p.280), Historical Statistics of the United States, 1976, p.827).

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



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

	Sample mean (1)	Log differences in outcomes: Above median vs. below median Δ in p.p. distance, 1930-1960		Difference (2)-(3) (4)
		Early Access (2)	Late Access (3)	
<i>Panel A. Farm Outcomes</i>				
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
<i>Panel B. Population and Employment</i>				
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 of robust standard errors at the 1% and 5% level, respectively.

Table 2: The effect of electricity access on rural outcomes

	Mean Dep. Var.	Coefficient on <i>DistPP</i> :				
		Effect of a 10 mile decrease in p.p. distance				
		(1)	(2)	(3)	(4)	(5)
Dependent Variables						
<i>A. Population and Employment</i>						
Rural Farm Pop.	8,488	68.63** (21.73)	38.84** (14.15)	36.77** (11.30)	38.47** (11.37)	30.53* (12.12)
Agr. Employment	2,606	34.18** (6.42)	27.50** (5.28)	23.44** (3.84)	24.79** (4.14)	24.75** (4.46)
<i>B. Agricultural Output</i>						
Log Farm Revenue	9.43	0.0070* (0.0029)	0.0059* (0.0029)	0.0060* (0.0029)	0.0064* (0.0029)	0.0074* (0.0030)
Number of Farms	1,937	12.92** (3.55)	10.29** (2.91)	9.56** (2.26)	9.36** (2.25)	8.98** (2.36)
Farmland	306,245	889.79 (584.67)	948.87 (588.15)	953.20 (589.60)	1,430.82* (652.18)	1,579.66* (720.07)
Farm Size	252	5.08 (3.12)	4.42 (3.07)	4.39 (3.08)	5.20+ (3.14)	5.47 (3.48)
Tractors per Farm	0.59	0.0052** (0.0018)	0.0051** (0.0018)	0.0054** (0.0018)	0.0060** (0.0018)	0.0068** (0.0019)
County & Year FE		Y	Y	Y	Y	Y
Linear State Trend		Y	Y	Y	Y	
Geographic Covariates		Y	Y	Y	Y	Y
Demographic Covariates			Y	Y	Y	Y
Economic Covariates				Y	Y	Y
Near MSA Covariates					Y	Y
State-Year FE						Y
		N(Observations) = 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. Standard errors are clustered at the county-level. **, * denote significance at the 1% and 5% level, respectively.

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

Dependent Variables	Mean Dep. Var. (1)	Coefficient on <i>DistPP</i> : Effect of a 10 mile decrease in p.p. distance				
		(2)	(3)	(4)	(5)	(6)
<i>A. Population</i>						
Rural Farm	8,488	68.63** (21.73)	38.84** (14.15)	36.77** (11.30)	38.47** (11.37)	30.53* (12.12)
Rural Non-Farm	9,335	-33.71 (30.04)	-4.46 (27.17)	5.47 (27.36)	8.91 (27.99)	2.49 (30.09)
Urban Population	7,345	-116.23+ (61.70)	44.51 (55.15)	41.36 (52.80)	71.06 (55.26)	80.34 (61.73)
Total	25,168	-81.30 (69.91)	78.89 (68.60)	83.60 (65.44)	118.44+ (69.61)	113.36 (76.11)
<i>B. Employment</i>						
Agriculture	2,606	34.18** (6.42)	27.50** (5.28)	23.44** (3.84)	24.79** (4.14)	24.75** (4.46)
Manufacturing	1,526	-41.58** (7.75)	-18.33** (6.78)	-17.80** (6.33)	-16.46** (6.33)	-16.98* (6.87)
Retail	1,138	-12.69* (5.31)	3.10 (4.45)	3.22 (4.39)	4.66 (4.59)	5.40 (5.05)
Construction	464	-4.06 (2.52)	0.51 (2.41)	0.60 (2.39)	1.21 (2.52)	1.78 (2.67)
Total	8,439	-26.18 (28.18)	31.99 (27.40)	30.40 (26.63)	39.21 (27.74)	39.58 (28.46)
<i>C. Sorting and Amenities</i>						
% White	86.9	-0.0501 (0.0723)	-0.0607 (0.0711)	-0.0630 (0.0711)	-0.0501 (0.0719)	-0.0341 (0.0790)
% of 25+ with High School	26.2	0.2236 (0.3459)	0.2428 (0.3650)	0.2469 (0.3693)	0.2629 (0.3874)	0.4727 (0.5934)
Log Retail Sales per Capita	0.86	0.0002 (0.0017)	-0.0001 (0.0016)	-0.0002 (0.0016)	-0.0006 (0.0016)	0.0009 (0.0016)
County & Year FE		Y	Y	Y	Y	Y
Linear State Trend		Y	Y	Y	Y	
Geographic Covariates		Y	Y	Y	Y	Y
Demographic Covariates			Y	Y	Y	Y
Economic Covariates				Y	Y	Y
Near MSA Covariates					Y	Y
State-Year FE						Y
		N(Observations) = 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. Standard errors are clustered at the county-level. **, * denote significance at the 1% and 5% level, respectively.

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

Dependent Variables	Mean	Coefficient on <i>DistPP</i> :				
	Dep. Var.	Effect of a 10 mile decrease in p.p. distance				
	(1)	(2)	(3)	(4)	(5)	(6)
<i>A. Property Values</i>						
Log Value of Farmland and Farm Buildings	5.41	0.0060** (0.0019)	0.0056** (0.0020)	0.0057** (0.0020)	0.0051** (0.0019)	0.0045* (0.0019)
Log Median Dwelling Value (Owner-Occupied)	9.87	0.0061** (0.0018)	0.0052** (0.0017)	0.0050** (0.0017)	0.0048** (0.0017)	0.0052** (0.0017)
Log Median Dwelling Rent (Renter-Occupied)	4.83	0.0049** (0.0013)	0.0038** (0.0013)	0.0039** (0.0013)	0.0038** (0.0013)	0.0037** (0.0013)
<i>B. Income Proxies</i>						
Log Farm Revenue Per Worker	1.86	-0.0034 (0.0026)	-0.0045+ (0.0026)	-0.0043+ (0.0026)	-0.0040 (0.0026)	-0.0017 (0.0026)
Log Retail Payroll Per Worker	2.24	0.0015 (0.0010)	0.0012 (0.0010)	0.0012 (0.0009)	0.0010 (0.0010)	0.0015 (0.0010)
Log Manufacturing Payroll Per Worker	2.31 (Obs=7,465)	0.0012 (0.0022)	0.0016 (0.0022)	0.0016 (0.0022)	0.0011 (0.0023)	0.0019 (0.0024)
County & Year FE		Y	Y	Y	Y	Y
Linear State Trend		Y	Y	Y	Y	
Geographic Covariates		Y	Y	Y	Y	Y
Demographic Covariates			Y	Y	Y	Y
Economic Covariates				Y	Y	Y
Near MS Covariates					Y	Y
State-Year FE						Y
		N(Observations) = 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. Standard errors are clustered at the county-level. **, * denote significance at the 1% and 5% level, respectively.

Table 5: Robustness tests

		Coefficient on <i>DistPP</i> : Effect of a 10 mile decrease in p.p. distance													
		Alternate samples				Restrict power plants									
Baseline estimates	Add controls for 1930 infrastructure	Drop counties <30 miles from a power plant	Drop counties west of 100th meridian	Drop counties with high elect. access in 1930	Drop TVA counties	Use only power plants ≥ 50 MW	Use only private power plants	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
<i>A. Population and Employment</i>															
Agr. Employment	24.7491** (4.4615)	26.2713** (4.3891)	17.4518** (5.3110)	18.8692** (3.9881)	19.9432** (4.4267)	28.9017** (4.5991)	17.6925** (4.7510)	13.0044* (5.2420)							
Rural Farm Population	30.5314* (12.1221)	35.5064** (12.0772)	19.6281 (13.4740)	13.7254 (14.2523)	26.2148* (12.4749)	42.3792** (12.4209)	17.6012 (11.7905)	21.5763 (14.8845)							
<i>B. Farm Output</i>															
Log Farm Revenue	0.0074* (0.0030)	0.0083** (0.0030)	0.0110** (0.0041)	0.0018 (0.0030)	0.0078* (0.0031)	0.0100** (0.0031)	0.0015 (0.0026)	0.0005 (0.0038)							
Number of Farms	8.9851** (2.3578)	10.0251** (2.3269)	4.5053 (2.9155)	8.8366** (2.7012)	8.3096** (2.4787)	12.7309** (2.4305)	7.4248** (2.4575)	6.5464* (3.1728)							
Farmland	1.579.66* (720.08)	1,587.40* (721.03)	2,015.52+ (1,052.78)	77.75 (440.69)	1,117.35+ (622.92)	1,680.75* (728.18)	1,030.53 (665.66)	-92.64 (708.70)							
Farm size	5.4671 (3.4807)	4.7597 (3.4631)	14.0085* (5.8620)	1.4807 (3.6285)	3.0857 (3.8515)	6.1750 (3.8278)	2.5624 (2.1269)	-3.0833 (3.4563)							
<i>C. Property Values</i>															
Log Value of Farmland and Farm Buildings	0.0045* (0.0019)	0.0043* (0.0020)	0.0046+ (0.0027)	0.0065** (0.0021)	0.0047* (0.0020)	0.0051* (0.0021)	0.0031* (0.0015)	0.0087** (0.0023)							
Log Median Dwelling Value (Owner-Occupied)	0.0052** (0.0017)	0.0047** (0.0017)	0.0049* (0.0022)	0.0080** (0.0019)	0.0058** (0.0018)	0.0047** (0.0018)	0.0053** (0.0016)	0.0095** (0.0022)							
Log Median Dwelling Rent (Renter-Occupied)	0.0037** (0.0013)	0.0032* (0.0013)	0.0020 (0.0017)	0.0056** (0.0015)	0.0038** (0.0014)	0.0041** (0.0014)	0.0035** (0.0012)	0.0055** (0.0018)							
<i>D. Income Proxies</i>															
Log Farm Revenue Per Worker	-0.0017 (0.0026)	-0.0020 (0.0026)	0.0040 (0.0036)	-0.0059* (0.0028)	-0.0014 (0.0027)	-0.0003 (0.0028)	-0.0069** (0.0021)	-0.0057+ (0.0033)							
Log Retail Payroll Per Worker	0.0015 (0.0010)	0.0014 (0.0010)	0.0002 (0.0013)	0.0031** (0.0011)	0.0014 (0.0010)	0.0009 (0.0010)	0.0020* (0.0009)	-0.0003 (0.0013)							
Log Manuf. Payroll Per Worker	0.0019 (0.0024)	0.0020 (0.0024)	-0.0001 (0.0036)	0.0039+ (0.0022)	0.0029 (0.0025)	0.0022 (0.0025)	0.0035+ (0.0019)	0.0044+ (0.0025)							
Full controls	Y	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. Standard errors are clustered at the county-level. **, * denote significance at the 1% and 5% level, respectively.

Table 6: Long-run effects of early electricity access

Panel A: Population and Employment Outcomes						
	Overall		Sectoral			
	Log Population (1)	Log Employment (2)	Log Emp. in Agr. (3)	Log Emp. in Mfg. (4)	Log Emp. in Retail (5)	Log Emp. in Construction (6)
Early Access ×						
1960	0.0347 (0.0236)	0.0318 (0.0242)	-0.0938** (0.0331)	0.1174+ (0.0630)	0.0757 (0.0502)	0.1004 (0.0642)
1970	0.0703* (0.0303)	0.0727* (0.0313)	-0.0449 (0.0406)	0.0743 (0.0673)	0.1040+ (0.0542)	0.1663* (0.0672)
1980	0.0940** (0.0356)	0.1030** (0.0382)	-0.0296 (0.0404)	0.0385 (0.0693)	0.1618** (0.0589)	0.1755* (0.0696)
1990	0.1272** (0.0403)	0.1457** (0.0441)	0.0030 (0.0391)	0.0769 (0.0722)	0.2067** (0.0637)	0.2376** (0.0754)
2000	0.1537** (0.0445)	0.1804** (0.0483)	0.0001 (0.0387)	0.1106 (0.0750)	0.2283** (0.0667)	0.2543** (0.0784)
Panel B: Property Values and Income						
	Property Values			Income Proxies		
	Log Med. Dwelling Value (Owner-Occ) (7)	Log Med. Dwelling Rent (Renter-Occ) (8)	Log Value Farmland and Farm Buildings (9)	Log Retail Payroll per Worker (10)	Log Mfg Payroll per Worker (11)	
Early Access ×						
1960	0.0411* (0.0208)	0.0229 (0.0187)	0.0168 (0.0219)	0.0272* (0.0114)	0.0402 (0.0260)	
1970	0.0531* (0.0242)	0.0472* (0.0194)	0.0627** (0.0221)	0.0293* (0.0132)	0.0462+ (0.0251)	
1980	0.0697** (0.0257)	0.0522** (0.0191)	0.0892** (0.0235)	0.0314* (0.0133)	0.0489+ (0.0273)	
1990	0.0998** (0.0274)	0.0569** (0.0198)	0.1182** (0.0301)	0.0201 (0.0132)	0.0575* (0.0286)	
2000			0.1383** (0.0305)	0.0319* (0.0138)	0.0646* (0.0288)	
Panel C: Farm Outcomes						
	Log Farm Population (12)	Log Farmland (13)	Log Farm Revenue (14)	Log Farm Rev. per Worker (15)		
Early Access ×						
1960	-0.0717* (0.0283)	-0.0757** (0.0197)	0.0188 (0.0347)	0.1127** (0.0335)		
1970	-0.0542 (0.0354)	-0.1084** (0.0271)	0.1694** (0.0419)	0.2165** (0.0579)		
1980	-0.0010 (0.0397)	-0.1101** (0.0316)	0.0806 (0.0494)	0.1077* (0.0506)		
1990	0.0293 (0.0399)	-0.1146** (0.0327)	0.0780 (0.0564)	0.0832 (0.0510)		
2000		-0.1274** (0.0349)	0.0578 (0.0632)	0.0577 (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% and 5% 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. (1)	Log Emp. (2)	Log Med. Dwell. Value (Owner-Occ) (3)	Log Med. Dwell. Rent (Renter-Occ) (4)	Log Value Farmland & Buildings (5)	Log Farm Population (6)	Log Farmland (7)	Log Farm Revenue per Worker (8)
Early Access × I(Near MSA) ×								
1960	0.0539 (0.0366)	0.0434 (0.0399)	0.0730* (0.0345)	0.0431 (0.0276)	0.0670* (0.0316)	-0.1365** (0.0436)	-0.1245** (0.0278)	0.1357** (0.0504)
1970	0.0845+ (0.0483)	0.0773 (0.0517)	0.0601+ (0.0357)	0.0641* (0.0273)	0.0991** (0.0336)	-0.1543** (0.0545)	-0.1980** (0.0412)	0.2856** (0.0898)
1980	0.1091+ (0.0578)	0.1138+ (0.0629)	0.1060** (0.0398)	0.0920** (0.0280)	0.1166** (0.0362)	-0.1279* (0.0619)	-0.2080** (0.0479)	-0.0662 (0.0790)
1990	0.1463* (0.0669)	0.1595* (0.0733)	0.1444** (0.0422)	0.0932** (0.0294)	0.1351** (0.0495)	-0.1313* (0.0623)	-0.2072** (0.0495)	-0.0128 (0.0878)
2000	0.1688* (0.0742)	0.1962* (0.0809)			0.1402** (0.0489)		-0.2237** (0.0533)	-0.0470 (0.0927)
Early Access × I(Far MSA) ×								
1960	0.0185 (0.0303)	0.0219 (0.0293)	0.0141 (0.0285)	0.0059 (0.0253)	-0.0257 (0.0300)	-0.0168 (0.0350)	-0.0409+ (0.0233)	0.0931* (0.0438)
1970	0.0583 (0.0380)	0.0688+ (0.0376)	0.0471 (0.0318)	0.0330 (0.0266)	0.0318 (0.0303)	0.0305 (0.0444)	-0.0401 (0.0305)	0.1580* (0.0746)
1980	0.0811+ (0.0437)	0.0938* (0.0461)	0.0391 (0.0324)	0.0185 (0.0257)	0.0662* (0.0309)	0.1063* (0.0492)	-0.0386 (0.0353)	0.2552** (0.0611)
1990	0.1111* (0.0484)	0.1341* (0.0521)	0.0620+ (0.0344)	0.0262 (0.0261)	0.1040** (0.0363)	0.1652** (0.0486)	-0.0472 (0.0366)	0.1646** (0.0550)
2000	0.1409** (0.0527)	0.1671** (0.0563)			0.1366** (0.0390)		-0.0587 (0.0389)	0.1462+ (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% and 5% level, respectively.

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

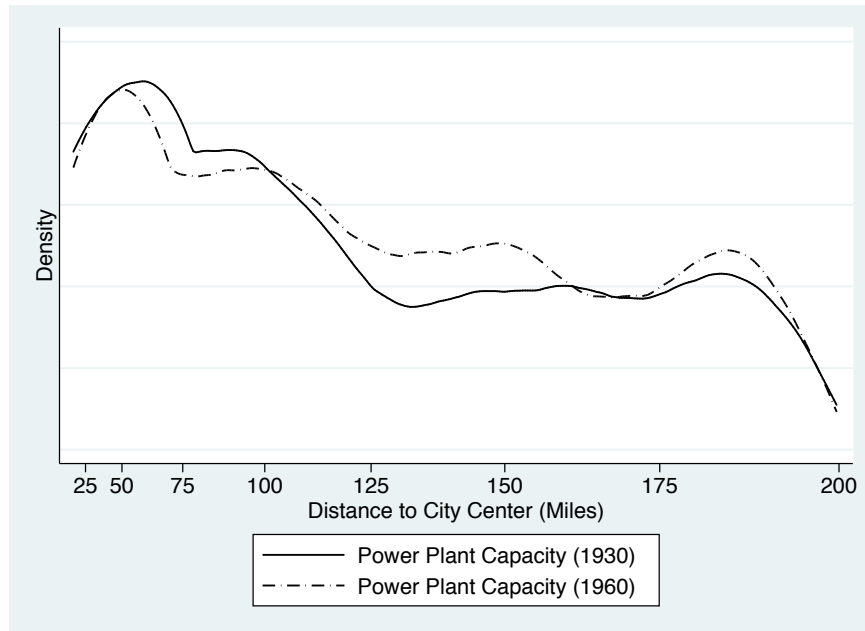
	Income proxies				Sorting			Amenities		
	Log Retail Payroll per Worker (1)	Log Mfg. Payroll per Worker (2)	Log Retail Sales per Capita (3)	% White (4)	% 25+ with HS Diploma (5)	% Housing Units Built in Prev. Decade (6)	Log Retail Emp. (7)	Log Construction Emp. (8)		
Early Access × I(Near MSA) ×					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

A Appendix (For Online Publication)

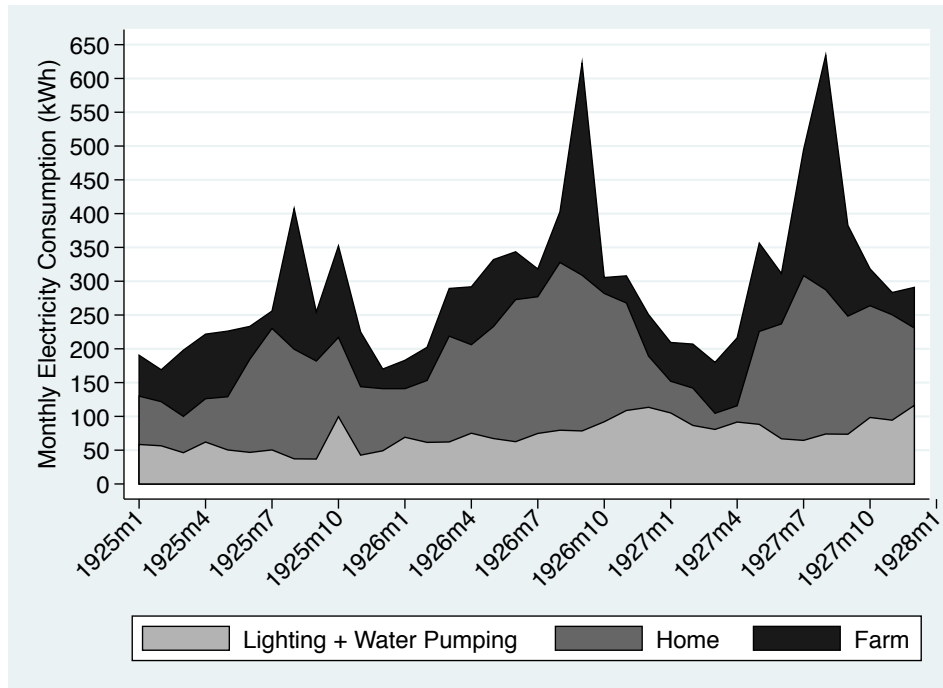
A.1 Figures and Tables

Figure A.1: Density of Electricity Capacity Around 50 Largest U.S. Cities in 1930 and 1960



Notes: This figure reports the density of generated capacity around the 50 largest U.S. cities in 1930 and 1960. For ease of interpretation, 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 data from Stewart, Larson, and Romness (1927).

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

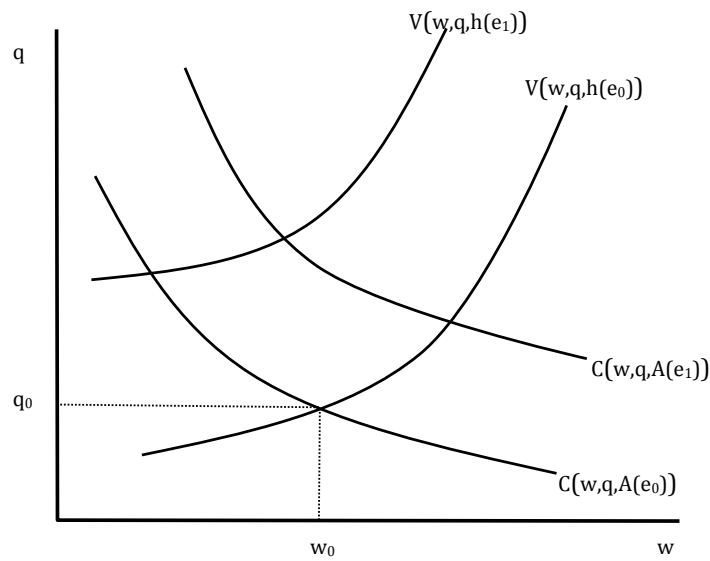
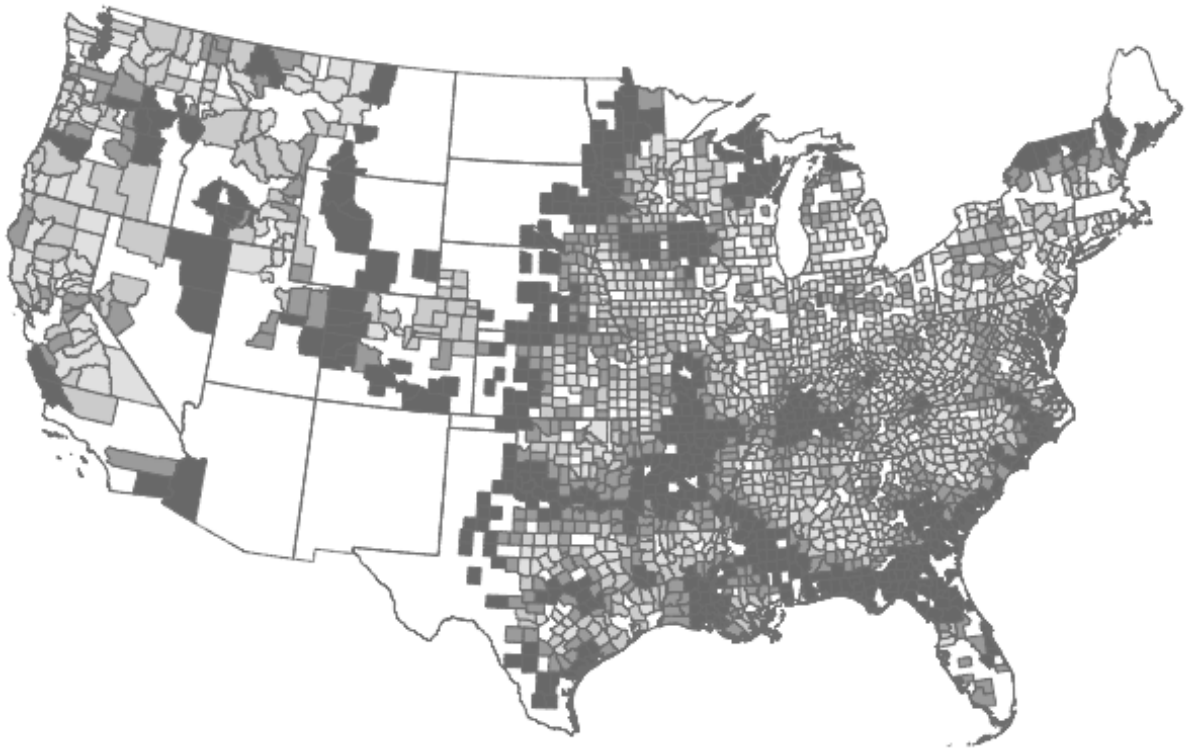


Figure A.4: Sample counties and power plant openings



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.

Table A.1: Farm Equipment and Home Appliances – January 1, 1928

Farm	1	2	3	4	5	6	7	8
Farm Equipment								
Barn equipment							X	X
Brooder	X	X	X	X	X	X		
Corn sheller								X
Feed grinder		X	X					
Feed mill					X	X		
Grain elevator								X
Hay hoist		X						X
Husker-shredder						X		
Incubator		X	X	X	X	X		
Milking machine			X			X		X
Motors	X	X	X		X	X	X	X
Pump jack		X				X	X	X
Root cutter		X						
Silo tiller							X	
Threshing machine								X
Ventilating fans							X	X
Wagon box elevator					X			
Home Appliances								
Bathroom equipment	X		X			X		X
Cream separator	X		X	X		X	X	X
Fans	X	X						
Fireless cooker			X	X				
Frying pan				X				
Griddle				X				
Heater	X	X	X	X		X		
Hot plate	X							
Iron	X	X	X	X	X	X	X	X
Ironing machine			X	X	X			
Laundry trays	X	X	X	X	X		X	
Milk warmer							X	
Oven				X				
Range	X	X	X		X	X	X	X
Refrigerator	X		X	X	X	X	X	
Sewing machine		X	X		X	X		X
Toaster				X			X	
Vacuum cleaner		X	X		X		X	
Washing machine	X	X	X	X	X	X	X	X
Water heater	X				X		X	X
Water softener								X
Basic Equipment								
Lighting	X	X	X	X	X	X	X	X
Water pump	X	X	X	X	X	X	X	X

Source: Authors' compilation based on Stewart, Larson, and Romness (1927).

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 (0.0266)	0.0587* (0.0260)	0.0269 (0.0246)	-0.0230 (0.0254)	-0.0150 (0.0314)	-0.0504* (0.0241)	0.0930* (0.0386)
1970	0.0509 (0.0346)	0.0880** (0.0321)	0.0425 (0.0259)	0.0154 (0.0255)	0.0286 (0.0384)	-0.0680* (0.0301)	0.0624 (0.0713)
1980	0.0746+ (0.0416)	0.1042** (0.0348)	0.0518* (0.0251)	0.0405 (0.0248)	0.1115* (0.0464)	-0.0438 (0.0361)	0.1159+ (0.0621)
1990	0.0939* (0.0477)	0.1076* (0.0517)	0.0419+ (0.0252)	0.0306 (0.0317)	0.1188** (0.0425)	-0.0432 (0.0390)	0.0381 (0.0602)
2000	0.1157* (0.0535)	0.1426* (0.0578)		0.0700* (0.0330)		-0.0526 (0.0416)	0.0471 (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 (0.0304)	0.0438 (0.0338)	0.0589* (0.0258)	0.0241 (0.0270)	-0.0325 (0.0342)	-0.0097 (0.0149)	0.0668 (0.0409)
1970	0.0961* (0.0391)	0.0877* (0.0429)	0.0786** (0.0295)	0.0920** (0.0291)	0.0197 (0.0482)	-0.0342 (0.0239)	0.0805 (0.0740)
1980	0.1122* (0.0451)	0.1198* (0.0504)	0.0767* (0.0321)	0.0984** (0.0309)	0.0316 (0.0527)	-0.0680* (0.0294)	0.1172 (0.0718)
1990	0.1564** (0.0515)	0.1740** (0.0579)	0.0981** (0.0343)	0.1237** (0.0376)	0.0937+ (0.0518)	-0.0500+ (0.0298)	-0.0016 (0.0636)
2000	0.1854** (0.0571)	0.2095** (0.0630)		0.1496** (0.0393)		-0.0399 (0.0313)	0.0202 (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% and 5% 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. Dwll. Value (Owner-Occ)	Log Med. Dwll. 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 (0.0232)	0.0337 (0.0238)	0.0412* (0.0209)	0.0232 (0.0187)	0.0175 (0.0219)	-0.0718* (0.0284)	-0.0763** (0.0196)	0.1137** (0.0334)
1970	0.0730* (0.0296)	0.0756* (0.0306)	0.0537* (0.0242)	0.0477* (0.0194)	0.0636** (0.0222)	-0.0537 (0.0355)	-0.1089** (0.0271)	0.2157** (0.0580)
1980	0.0985** (0.0350)	0.1068** (0.0373)	0.0704** (0.0258)	0.0526** (0.0191)	0.0896** (0.0235)	-0.0004 (0.0399)	-0.1109** (0.0315)	0.1082* (0.0507)
1990	0.1314** (0.0394)	0.1505** (0.0429)	0.1009** (0.0274)	0.0576** (0.0198)	0.1193** (0.0301)	0.0300 (0.0401)	-0.1154** (0.0327)	0.0820 (0.0507)
2000	0.1585** (0.0434)	0.1859** (0.0469)			0.1392** (0.0305)		-0.1280** (0.0349)	0.0581 (0.0603)
1944 Interstate Highway Plan ×								
1960	0.1188** (0.0254)	0.1170** (0.0258)	0.0091 (0.0202)	0.0183 (0.0174)	0.0425* (0.0213)	-0.0045 (0.0271)	-0.0369 (0.0239)	0.0617 (0.0391)
1970	0.1634** (0.0320)	0.1780** (0.0329)	0.0382+ (0.0216)	0.0256 (0.0166)	0.0659** (0.0231)	0.0322 (0.0311)	-0.0353 (0.0281)	-0.0558 (0.0553)
1980	0.2006** (0.0366)	0.2323** (0.0392)	0.0370 (0.0234)	0.0265 (0.0170)	0.0292 (0.0257)	0.0358 (0.0340)	-0.0524+ (0.0315)	0.0283 (0.0508)
1990	0.2520** (0.0413)	0.2887** (0.0448)	0.0641** (0.0246)	0.0437* (0.0173)	0.0689* (0.0302)	0.0553 (0.0337)	-0.0469 (0.0329)	-0.0843+ (0.0495)
2000	0.2930** (0.0444)	0.3307** (0.0482)			0.0561+ (0.0327)		-0.0379 (0.0336)	0.0258 (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% and 5% 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,⁵³ 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:

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

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.⁵⁴ 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:

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

Equilibrium prices, (w, q^R, q^U) , 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

⁵³The 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.

⁵⁴Since 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 4 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 $C(w, q, A(e_0))$ 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, $A(e_0)$. The upward-sloping curve, $V(w, q, h(e_0))$, 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.⁵⁵ Initial equilibrium prices are determined by the intersection of these curves at (w_0, q_0) .

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 .⁵⁶ 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 $C(w, q, A(e_1))$. 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.⁵⁷

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 $V(w, q, h(e_1))$, 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. In Figure 4, 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

⁵⁵The curvature of these functions depends on the degree of complementarity in production (between labour and land) and utility (between consumption and land).

⁵⁶The effects on agricultural land price and land use will depend on the elasticity of demand for land in the urban sector.

⁵⁷In 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:

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

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:

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

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:

$$p_e^* N^R + [-C_e X^R] = \frac{dq}{de} L^R. \quad (\text{A.5})$$

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.