The Impacts of Depopulation and Climate Change on the Cost of Rural Electric Services[1]

Liqing Li[2] **R. Aaron Hrozencik**[3] **Mani Rouhi Rad**[4] **Dilek Uz**[5][6]

Selected Paper prepared for presentation at the 2024 Agricultural & Applied Economics Association Annual Meeting, New Orleans, LA; July 28-30, 2024

[1] ∗The findings and conclusions in this manuscript are those of the authors and should not be construed to represent any official USDA or U.S. government determination or policy
[2] Texas A&M University, Department of Agricultural Economics, liqing.li@ag.tamu.edu
[3] USDA-Economic Research Service, Resource and Rural Economics Division, aaron.hrozencik@usda.gov
[4] Texas A&M University, Department of Agricultural Economics, mani.rouhirad@ag.tamu.edu
[5] University of Nevada, Reno, Department of Economics, dilekuz@unr.edu
[6] Last three authors are listed in alphabetical order.

The Impacts of Depopulation and Climate Change on the Cost of Rural Electric Services *

Liqing Li[†] R. Aaron Hrozencik[‡] Mani Rouhi Rad[§] Dilek Uz[¶][‖]

May 14, 2024

PRELIMINARY DRAFT, PLEASE DO NOT CITE OR DISTRIBUTE

Abstract

The rural population in the US bears a disproportionate burden in terms of energy expenses, which can consume up to 10% of their household income. Two significant current trends, depopulation and climate change, could exacerbate this issue. Depopulation may lead to a significant decline in the customer base for electricity utilities, potentially driving up electricity bills as the fixed costs of maintaining and operating distribution networks are spread across fewer customers. Furthermore, climate change could increase household electric bills by elevating maintenance costs due to the accelerated depreciation of capital assets amidst more frequent extreme weather events. This paper examines the impact of changing populations and climate on electricity expenditures among rural consumers, leveraging a novel dataset that characterizes the operations of rural electricity cooperatives. We find increasing temperatures increase operation and maintenance costs in the short-run. Moreover, we find asymmetrical effects of population increases and decreases on revenues collected from residential electric customers in the short term. When a utility's customer base shrinks, the remaining customers face higher electricity bills as the utility passes on fixed costs (for operation and maintenance) to them. However, in the long term, utilities adjust to alleviate the burden of fixed costs on the remaining customers.

*The findings and conclusions in this manuscript are those of the authors and should not be construed to represent any official USDA or U.S. government determination or policy.

[†]Texas A&M University, Department of Agricultural Economics, liqing.li@ag.tamu.edu
[‡]USDA-Economic Research Service, Resource and Rural Economics Division, aaron.hrozencik@usda.gov
[§]Texas A&M University, Department of Agricultural Economics, mani.rouhirad@ag.tamu.edu
[¶]University of Nevada, Reno, Department of Economics, dilekuz@unr.edu
[‖]Last three authors are listed in alphabetical order.

1 Introduction

The rural population in the US bears a disproportionate burden in terms of energy expenses. This issue is even more severe among low-income rural households, who may spend 10% of their household income on energy bills (Ross et al., 2018). Several factors can contribute to high energy bills in rural areas. For instance, extending and maintaining the electrical grid in rural areas can be more expensive per capita due to greater distances between homes and lower population density.

Two significant current trends, depopulation and climate change, might exacerbate this issue. Depopulation has affected select areas of rural America for nearly a century, leading to the first-ever recorded decline in aggregate population in rural US counties between 2010 and 2016 (Johnson and Lichter, 2019). According to the 2020 US Census (U.S. Census, 2020), more than half of the counties lost population between 2010 and 2020. This trend exacerbated during the Covid-19 pandemic due to a high mortality and low birth rates of an aging society. While only 6% of metropolitan counties have experienced depopulation, more than 80 percent of rural farm counties are depopulating due to mechanization and consolidation within the agricultural sector (Anderlik and Cofer Jr, 2014).

In the U.S., utilities for water, natural gas, and electricity operate as natural monopolies, typically recovering fixed costs by spreading fees over their customer base. Depopulation in rural areas can lead to a significant decline in the customer base for public services such as water and electricity utilities (Swain et al., 2020; Davis and Hausman, 2022). About 50% of rural utilities in the US have experienced at least one decline in customer base within a 3-year period. Depopulation can significantly impact the cost recovery mechanisms of these utilities. In responding to a declining customer base, utilities need to cut the costs of maintaining and operating distribution networks or share the costs across a shrinking customer base, driving up utility bills.

In addition to depopulation, climate change could significantly impact these households' electricity bills through two distinct mechanisms. First, it is well-documented in the literature that hotter temperatures increase household electricity demand and consumption (e.g.,Scott and Huang (2007); Lal et al. (2011)). Second, the increased frequency of extreme weather events, such as extreme heat or wildfires, can accelerate the depreciation of capital assets, such as transmission and distribution networks (Ward, 2013), which may increase the maintenance costs of the network that needs to be spread across the existing customers.

Both depopulation and climate change may accelerate the increase in electricity bills for a rural population that already spends a higher percentage of their income on energy compared to urban households (Ross et al., 2018). Therefore, understanding how rural population decline and climate change affect operational costs and rural energy costs is critical for proper infrastructure planning and formulating climate change adaptation and rural development policies. This paper examines how changing climates and depopulation impact electricity expenditures among rural consumers by leveraging a novel dataset characterizing the operations of rural electricity cooperatives (RECs). RECs typically operate under a cost-recovery business model, mainly serving rural areas in the U.S. The revenue collected from customers is used to cover two types of costs: power-purchasing costs, which are the expenses utilities incur in buying electricity from third-party generators and transmitting it to rural customers, and non-power costs, which include legacy costs for operating the utility such as maintenance, operation, and labor. RECs typically recover non-power costs by spreading fees out over their customer base.

The USDA Rural Utilities Service (RUS) provides subsidized loans for Rural Electric Cooperatives (RECs) to invest in distribution, transmission, and generation infrastructure. RECs that have borrowing relationships with RUS are required to file annual reports detailing revenue, operational costs, miles of electricity distribution, the number of full-time employees, and the number of customers by sector (commercial, residential).

These data are available annually from 1992 to 2019 for more than 420 electricity distribution utilities serving the residential and commercial sectors across a vast swath of the U.S. To further examine the relationship between increasing temperatures and RECs' operations, we complement these data with additional weather data from PRISM, characterizing temperatures aggregated to the utility service area.

We model how RECs' operations and rural electricity expenditures respond to changes in the customer base and climate in both the short-run and long-run. First, we use a first-difference model to explore how rural electricity expenditures react to variations in the residential customer base and rising temperatures in the short run. Our short-run results demonstrate that changes in miles of distribution and maintenance and operation costs are relatively inelastic in response to a shrinking customer base, suggesting that a decreasing customer base increases the fixed costs borne by the remaining customers in the short term. Additionally, rising temperatures increase maintenance and operation costs, which results in higher bills to cover the non-power costs in the short term. Second, we utilize a long-difference model, following Burke and Emerick (2016), to examine how utilities' operational decisions respond to long-term changes in climate and customer base by measuring changes in operational cost and residential customer bills. Our long-run results indicate that utilities can make some operational adjustments to mitigate the direct impact of a diminishing residential customer base on the remaining customers' electricity bills.

This paper makes significant contributions to four areas within the existing literature. First, it addresses a gap concerning the operations of RECs. RECs have not received much attention in discussions on electric energy in the U.S.(Gilcrease et al., 2022; Velaga et al., 2019), with more existing studies focusing on Investor-Owned Utilities (IOUs) (Fares and King, 2017). Unlike RECs, IOUs are for-profit electricity utilities that serve over 80% of the U.S. population and are heavily regulated by state and federal laws regarding pricing and operations. As a result, much of the research has centered on regulatory oversight (e.g., Averch and Johnson (1962); McRae (2015)), aiming to minimize the cost impacts of regulations without degrading service quality. Only a few studies have compared RECs and IOUs in terms of energy efficiency and pricing (e.g., Petersen (1991); Wilson et al. (2008); Dan Berry (1994)). However, it is crucial to recognize that RECs are the primary utilities serving rural areas—regions where the return on expensive infrastructure investments was not high enough to attract IOUs. Although RECs serve only 13% of the U.S. population, they own more than 50% of the landmass and are a major type of electricity utility in the U.S. Therefore, understanding how RECs operate in rural areas, particularly in the face of population decline in rural areas, is essential.

Second, the paper contributes to broader discussions on infrastructure investment and fixed cost recovery of natural monopolies. Specifically, we contribute to a previously under-studied issue on customer base loss and the recovery of legacy costs. To the best of our knowledge, only Davis and Hausman (2022) have examined the impact of a decrease in the customer base in the transition from natural gas to electricity. Their results highlight the short-term impacts on customer bills due to shrinking customer bases in the natural gas sector. However, due to the nature of the natural gas utilities industry in the U.S., Davis and Hausman (2022) focus on how IOUs and public-owned utilities respond to a declining customer base. Our paper extends the body of knowledge by focusing on RECs, offering new insights into how utilities might respond to a shrinking customer base and the strategies they employ to recover legacy costs. In addition, Davis and Hausman (2022)'s study was limited by data constraints, relying solely on customer base size and annual revenue metrics. In contrast, our study utilizes comprehensive operation data from the RUS, which includes detailed information on operational costs and staffing levels, thereby allowing a more nuanced exploration of the mechanisms at play. Moreover, while Davis and Hausman (2022) suggests that a decreasing customer base in natural gas can increase customer bills in the short term, the impact, in the long run, remains unclear. In the long run, utilities may have more flexibility in making adjustments to operational decisions, which can alleviate the impact on customer bills. Hence, this paper examines both the short- and long-term impacts of changing customer bases on the cost of rural electricity use.

Third, this paper explores the implications of rural depopulation. Following the Rural Electrification Act of 1936, there was a significant expansion in electricity access in rural areas. While earlier research has explored the value of cooperatives in rural electrification (Yadoo and Cruickshank, 2010) and its economic impacts in rural U.S., both short-term and long-term (Lewis and Severnini, 2020), current research is needed to understand the ongoing challenges faced by these areas due to declining populations. Rural depopulation may lead to disruptions in basic public services (Sutradhar et al., 2024) and can exacerbate income inequality (Butler et al., 2020). Existing research show a shrinking customer base can lead to urban water shutoff due to high water bills (Faust et al., 2016; Swain et al., 2020) and reduced reliability and service quality in landline phone services (Gabel and Burns, 2012). As such, this study seeks to understand the impact of population loss on rural residents who remain, particularly in terms of their energy costs.

Fourth, we contribute to the literature on the impact of climate change on residential energy bills. While existing economic literature shows that residential electricity bills would increase with higher temperatures due to increasing demand for electricity (e.g., Bartos and Chester (2015); Auffhammer et al. (2017), a few emerging papers focus on the vulnerability and resilience of the electricity infrastructure. Through modeling, they suggest that rising temperatures could lead to a reduction in safety capacity for electricity generators and transmissions (Panteli and Mancarella, 2015; Burillo et al., 2019), which may result in higher demands for maintenance. However, the direct cost of increasing temperature on the operation and maintenance of electricity remains unclear. To the best of our knowledge, our paper is the first to quantify the impact of increasing temperatures on utilities' operational and maintenance costs, as well as its direct impact on residential energy bills.