THE IMPACTS OF DEPOPULATION AND CLIMATE CHANGE ON THE COST OF RURAL ELECTRIC SERVICES

[Liqing Li, Texas A&M University, liqing.li@ag.tamu.edu]
[R. Aaron Hrozencik, University of Georgia, Robert.Hrozencik@uga.edu]
[Mani Rouhi Rad, Texas A&M University, Mani.RouhiRad@ag.tamu.edu]
[Dilek Uz, University of Nevada, dilekuz@unr.edu]

Section 1:

The rural population in the US carries a disproportionate burden in energy bills. Two important current trends, depopulation and climate change, might exacerbate this issue. Depopulation has affected select areas of rural America for nearly a century. Based on decennial census data, more than 54 percent of all rural counties lost population between 1990 and 2020, with declines commonly ranging from 10 to 30 percent, and some counties experiencing losses of up to 60 percent. Depopulation in rural areas can lead to a significant decline in the size of the utilities' (e.g., electricity and water) customer base. About 50% of rural utilities in the US have at least experienced a one-time population decline over a three-year span. This has a significant impact on the cost recovery mechanism of these utilities, as the non-power purchasing costs of maintaining and operating distribution networks will eventually have to be spread across fewer customers driving up electricity bills.

In addition to depopulation, climate change has the potential to play an important role in these households' electric bills via two distinct mechanisms. First, it is well-documented in the literature that hotter temperatures increase household electricity demand and consumption (e.g., Auffhammer (2022)). Second, the increased frequency of extreme weather events, such as extreme heat, can heighten the vulnerability of the electricity infrastructure, particularly transmission and distribution networks (Bollinger and Dijkema, 2016). Consequently, the maintenance costs of the network, which need to be spread across the existing customers, might increase.

In summary, 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 or climate change affects utilities' operations and rural energy costs is critical for proper infrastructure planning and formulating climate change adaptation and rural development policies prioritizing social and environmental justice issues. This paper examines how changing climate and depopulation impact electricity expenditures among rural consumers by leveraging a novel annual dataset characterizing the operations of rural electricity cooperatives (RECs).

Section 2:

RECs are generally run via a cost-recovery business model where they purchase electricity from third party generators and transmit and sell to rural customers. USDA Rural Utilities Service (RUS) provides subsidized loans for RECs to invest in distribution, transmission, and generation infrastructure. RECs with a borrowing relationship with RUS are required to file annual reports with information on revenue and operation. To estimate the empirical models, we utilize novel the administrative data from USDA-RUS that describe the operations of more than 400 RECs from 1992 to 2019. This administrative data is integrated with PRISM weather data, allowing us to explore how rural electricity service costs are influenced by changes in climate and population.

We model how RECs' operations and rural electricity expenditures respond to changes in temperature and the customer base both in 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 temperatures in the short run. Second, we utilize a long-difference model as outlined in 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. The outcome variables include the miles of distribution, the maintenance and operation costs, the number of full time employees, and the non-power purchasing cost (net revenue).

Section 3:

Our short-run results demonstrate that changes in miles of distribution lines, operations and maintenance costs, and the number of full-time employees do not respond to a shrinking customer base, suggesting that a decreasing customer base increases the per capita non-power purchasing costs borne by the remaining customers in the short run. Additionally, rising temperatures increase operations and maintenance costs, which result in higher bills to cover the non-power costs in the short run. We also apply a panel fixed effects model to examine how operations and maintenance costs, as well as energy demand, change in response to temperature exposure. The findings confirm the impact of climate change on energy bills in the short run. Our long-run results indicate that utilities seem to be able to make some operational adjustments to mitigate the direct impact of a diminishing residential customer base on the remaining customers' electricity bills.

Section 4:

This paper contributes to three areas within the existing literature. First, it contributes to the literature on RECs' operations, which has received less attention compared to Investor Owned Utilities (IOUs) (Gilcrease et al., 2022; Fares and King, 2017). IOUs –for-profit electricity utilities serving over 80% of the U.S. population - are heavily regulated by state and federal laws. In contrast, RECs serve rural regions where returns on infrastructure investments are generally insufficient to attract IOUs. RECs are non-profit electricity providers. Consumers are members and users of the utility (Gilcrease et al., 2022). REC customers/members elect board members to represent their interests through managerial and administrative decision-making. Voting rights are conferred on customers/members according to a one-member, one-vote rule, which is not tied to property ownership. The distinct ownership and governance structure of RECs has allowed them to be largely exempt from regulation at the federal level and in a majority of states. Only a few studies have discussed RECs' operations in terms of energy efficiency and pricing (e.g., Wilson et al. (2008); Dan Berry (1994)). Therefore, understanding how RECs operate, particularly in the face of population decline and climate change, is essential for improving the sustainability of rural communities.

Second, the paper contributes to broader discussions on infrastructure investment and fixed cost recovery in natural monopolies. Existing literature has raised concerns that, given the economies of scale associated with electricity distribution, retail utility rates often deviate from the private marginal cost (Borenstein and Bushnell, 2022). However, limited research has addressed the issue of shrinking customer bases and legacy cost recovery. To our knowledge, only Davis and Hausman (2022) have examined the impact of decreasing customer bases in the context of the transition from natural gas to electricity, focusing on the short-run impacts on customer bills. 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 RECs respond to a shrinking customer base and how they recover legacy costs. Notably, our dataset includes detailed information on operational costs and staffing levels, allowing for a more nuanced analysis. Additionally, we examine both short- and long-run effects on rural electricity costs, considering the potential flexibility utilities have in adjusting operations over time.

Third, 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)), many earlier studies rely on crosssectional or time-series data. More recent papers use panel data to control for unobserved heterogeneity but often rely on aggregate-level data (e.g., state-level energy consumption) (Deschenes and Greenstone, 2011) or focus on specific geographies (e.g., household- level data in California (Auffhammer and Aroonruengsawat, 2011, 2012)). There remains a lack of causal estimates that quantify the temperature–consumption relationship across broader geographies using more granular data (Auffhammer and Mansur, 2014; Auffhammer, 2022). Our study contributes to this literature by providing utility-level panel data evidence on the relationship between temperature and energy consumption for rural areas in the U.S.

More importantly, our paper goes beyond demand-side effects to estimate the impact of extreme temperatures on utility infrastructure, specifically on non-power purchasing costs such as operations and maintenance. A few emerging papers focus on the resilience of the electricity infrastructure and efficiency in energy transmission. Through modeling, they suggest that rising temperatures could lead to a reduction in safety capacity for electricity infrastructure (Panteli and Mancarella, 2015; Burillo et al., 2019) and reduce energy transmission efficiency because of high energy loss and additional cooling requirements (Doss-Gollin et al., 2023), which may result in higher costs for operations and increased demands for maintenance. However, the direct cost of increasing temperature on the operations and maintenance of electricity remains unclear. To the best of our knowledge, our paper is the first to econometrically quantify the impact of increasing temperatures on utilities' operations and maiantance costs, as well as their direct impact on residential energy bills.

Reference

Auffhammer, M. (2022). Climate adaptive response estimation: Short and long run impacts of climate change on residential electricity and natural gas consumption. Journal of Environmental Economics and Management, 114:102669.

Auffhammer, M. and Aroonruengsawat, A. (2011). Simulating the impacts of climate change, prices and population on california's residential electricity consumption. Climatic change, 109:191–210.

Auffhammer, M. and Aroonruengsawat, A. (2012). Erratum to: Simulating the impacts of climate change, prices and population on california's residential electricity consumption. Climatic Change, 113:1101–1104.

Auffhammer, M., Baylis, P., and Hausman, C. H. (2017). Climate change is projected to have severe impacts on the frequency and intensity of peak electricity demand across the united states. Proceedings of the National Academy of Sciences, 114(8):1886–1891.

Bartos, M. D. and Chester, M. V. (2015). Impacts of climate change on electric power supply in the western united states. Nature Climate Change, 5(8):748–752.

Bollinger, L. A. and Dijkema, G. P. (2016). Evaluating infrastructure resilience to extreme weather–the case of the dutch electricity transmission network. European Journal of Transport and Infrastructure Research, 16(1).

Borenstein, S. and Bushnell, J. B. (2022). Do two electricity pricing wrongs make a right? cost recovery, externalities, and efficiency. American Economic Journal: Economic Policy, 14(4):80–110.

Burillo, D., Chester, M. V., Pincetl, S., and Fournier, E. (2019). Electricity infrastructure vulnerabilities due to long-term growth and extreme heat from climate change in los angeles county. Energy Policy, 128:943–953.

Burke, M. and Emerick, K. (2016). Adaptation to climate change: Evidence from US agriculture. American Economic Journal: Economic Policy, 8(3):106–40.

Dan Berry, M. (1994). Private ownership form and productive efficiency: Electric cooper- atives versus investor-owned utilities. Journal of Regulatory Economics, 6(4):399–420.

Davis, L. W. and Hausman, C. (2022). Who will pay for legacy utility costs? Journal of the Association of Environmental and Resource Economists, 9(6):1047–1085.

Deschênes, O. and Greenstone, M. (2007). The economic impacts of climate change: evidence from agricultural output and random fluctuations in weather. American Economic Review, 97(1):354–385.

Doss-Gollin, J., Amonkar, Y., Schmeltzer, K., and Cohan, D. (2023). Improving the representation of climate risks in long-term electricity systems planning: a critical review. Current Sustainable/Renewable Energy Reports, 10(4):206–217.

Fares, R. L. and King, C. W. (2017). Trends in transmission, distribution, and administration costs for us investor-owned electric utilities. Energy Policy, 105:354–362.

Panteli, M. and Mancarella, P. (2015). Influence of extreme weather and climate change on the resilience of power systems: Impacts and possible mitigation strategies. Electric Power Systems Research, 127:259–270.

Ross, L., Drehobl, A., and Stickles, B. (2018). The high cost of energy in rural America: Household energy burdens and opportunities for energy efficiency. Washington DC: American Council for an Energy Efficient Economy.

Wilson, E. J., Plummer, J., Fischlein, M., and Smith, T. M. (2008). Implementing energy efficiency: Challenges and opportunities for rural electric co-operatives and small mu- nicipal utilities. Energy policy, 36(9):3383–3397.