Residential Welfare-Loss from Electricity Supply Interruptions in South Africa: Cost-Benefit Analysis of Distributed Energy Resource Subsidy Programs

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1. Motivations underlying the research

Sub-Saharan Africa has one of the highest population growth projections among major global regions but one of the lowest electrification rates. Only 47% of households access electricity, while the population is expected to double to 2.2 billion within 30 years. Without improvements, this would leave over 1 billion people in the region without electricity. Those countries that do have well-developed electrical grids still often face a second major obstacle: grid reliability. South Africa provides grid electricity to over 90% of residents, but—like many of its regional neighbors—suffers chronic electricity shortages. While households have access, they must live around shortages, which occur regularly and can last for hours. The costs of adjusting can be substantial, especially for low-income households that depend on electricity. Reliable electricity maintains good air quality, helps improve literacy rates, increases free time for household members to devote to leisure and productive activities, and prevents emergency expenditures during a shortage, among many other benefits. With each hour of outage, these benefits slip away. Distributed energy resources, or DERs, (e.g., solar panels and batteries) offer households a solution by providing off-grid electricity resources to temporarily bridge the gap in electricity supply during a grid shortage. Off-grid electricity resources have already grown rapidly as a cost-effective solution to electricity access and reliability in the Sub-Saharan region, and more growth is needed to help keep supply at pace with future population growth. More research is needed to understand the benefits of off-grid technologies and how to deploy them to households in an affordable and scalable way.

2. Short account of research performed

The purpose of this paper is to use a market-based estimation of welfare-loss from electricity interruptions in order to determine whether distributed energy resources are a cost-effective solution for South African households. I use market data on electricity prices and consumption across 16,851 households to estimate residential welfare-loss from an electricity interruption and thereby how much households are willing to pay to avoid an outage. A two-part model uses regressors for household appliances and characteristics, electricity consumption, and price and income elasticities to determine welfare-loss from interruptions. I compare the willingness-to-pay to avoid an interruption to the cost of purchasing solar panels and batteries to determine the cost-effectiveness of investing in off-grid electricity across various scenarios. Solar panel products are varied by cost and electricity output. Government subsidy scenarios are also varied since investment costs often exceeds annual household income. Results are reported across income deciles to illuminate differences in off-grid benefits and costs between low-income and high-income households. This provides relevant insight on the interaction between income inequality and electricity in South Africa.

3. Main conclusions and policy implications

The results show that lower-income households are disproportionately affected by electricity interruptions in terms of relative welfare-loss. Welfare-loss in the lowest two income deciles equates to 6-14% of household income, but less than 0.5% for the top two income deciles. In the lowest income decile, welfare-loss as a portion of income is more than twice that of all other deciles, indicating that this group is disproportionately harmed by interruptions. The cost-benefit analysis shows that with at least a

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40% government subsidy of investment costs, residential distributed energy resources are a cost-effective investment for households. To be cost-effective, the DERs must prevent more lifetime welfare-loss than their cost to acquire—both measured in time-adjusted US dollars. At the societal level, the aggregate benefit across all households in positive cost-benefit scenarios exceeds total spending for government subsidies in several cases. For instance, spending $1 Billion to subsidize low-output DERs for the lowest income decile households prevents $1.5 Billion in lifetime welfare-loss—a 50% return on investment. Positive social return-on-investment outcomes were also found for other income deciles. The main implication for policy-makers is that prioritizing subsidies for lower income deciles provides the most "bang for buck" in terms of net social and economic gains. Subsidizing DERs in this way would reduce welfare-loss inequality from electricity interruptions, while leading to a healthier population, a more stable electrical grid, and more productive households.