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What could explain low uptake of rural electricity programs in Africa? Empirical evidence from rural Tanzania

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What Could Explain Low Uptake of Rural Electricity Programs in Africa? Empirical Evidence from Rural Tanzania

Abstract

Increasing electricity access remains a challenge, particularly in rural areas of sub-Saharan Africa. This study examines the case of Tanzania, where rural connection rates remain low even among households residing “under the grid”, and this despite substantial government subsidies for household connections. Using data from 1774 rural households living within reach of the electricity grid, we investigate correlates of the low grid electricity uptake. We find that proxies for wealth, including housing characteristics, are positively associated with connection status, while social network variables are less so. Capacity to pay thus appears to remain a major barrier, and in-house wiring costs emerge as a significant expense unaccounted for by the subsidy scheme, exceeding the cost of grid connection by a factor of eight. We also find that similar mechanisms govern choices between grid electricity and traditional or solar energy sources. Together, these findings inform the ongoing policy debate regarding on-grid versus off-grid energy solutions.

JEL-Codes: D12, O13, O33, Q41

Keywords: Electrification; household decision; electricity access; Tanzania; energy transition

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1. Introduction

Achieving the Sustainable Development Goal (SDG) 7 of universal access to electricity by 2030 will require additional efforts. Access deficits are particularly chronic in rural sub-Saharan Africa, where the number of people without access in 2021 was around 450 million, more people than in 2010 (IEA et al. 2023). This is despite heavy investment by several governments in the region to improve rural access to grid electricity (cf. Lenz et al. 2017, for example). The government of Tanzania has devoted significant effort and resources to a rural electrification program since 2007. Under this program, households have to pay only the equivalent of USD 13 to get connected to grid electricity, as opposed to the normal connection price of USD 80. Despite such huge subsidies, household connections have remained low, even among those residing along the grid line (Chaplin et al. 2017). Low grid electricity uptake has also been found in other sub-Saharan African countries, including Burkina Faso (Schmidt and Moradi 2023) and Kenya (Lee et al. 2016). Lee et al. (2020) later randomly allocated rural connection subsidies in Kenya and diagnosed a sharp decline in connection rates as fees increase: while almost all households connected if connection was for free, a subsidy equivalent to 57% or 29% increased connection rates by only 23 and 6 percentage points, respectively, with similar findings provided by Bernard and Torero (2015). Beyond connection costs as a potential driver, relatively little is known about drivers and barriers of household grid connections (Bonan et al. 2017).

This paper looks closer into the low rural uptake of grid electricity by testing various potential correlates of uptake among households living within reach of the electricity grid in rural Tanzania. Unlike Kenya, the government of Tanzania has largely subsidized rural electricity connection fees. This raises a question about the relevance of high connection fees as a driver of the low uptake. While the running costs of electricity are another obvious and frequently cited reason for non-connection (Bos et al. 2018), this paper focusses on key household-specific characteristics as potential determinants. In light of a relatively high penetration rate of individual solar photovoltaic (PV) systems even among households living within reach of the electricity grid, we also assess the choice between grid electricity and decentralized solar solutions to shed more light on this aspect of the rural energy transition.

For this analysis, we use information from both connected and non-connected households in electrified communities collected with a carefully designed sampling frame and survey instrument. The study sample comprises 1774 households from 43 rural hamlets located in central Tanzania. Using cross-sectional data applied to simple binary and multinomial logit models, we find that household income and wealth proxies, and – only selectively – social network variables play important roles in connection status, paralleling the findings of other technology adoption studies (see, for example, Lewis and Pattanayak 2012 and Jaime et al. 2020). These associations are found when assessing the choice between grid electricity and traditional energy sources, as well as between grid electricity and solar energy. These results hint at the importance of other cost barriers, and we briefly discuss one candidate, in-house wiring, with costs many times higher than those for grid connections in rural Tanzania.

The remainder of this paper is organized as follows. Section 2 provides contextual background on energy access in rural Tanzania. Section 3 describes the methodology of the study, including sampling and data collection and the estimation strategies. Section 4 presents the results, including both descriptive statistics and main estimation results. Section 5 concludes the study.

2. Energy Access in Tanzania: Trends and Interventions

The household sector consumes the highest share of the country's primary energy (73%) and 40% of electricity (URT 2015; Sander et al 2013; Lusambo 2016; Mkoma and Mabiki 2011). By 2021, 43% of all households and 23% of rural households were connected to electricity, rates that are low even for sub-Saharan African standards (IEA et al. 2023). In the poor rural setting, lighting is the primary use of electricity. Households have clearly been moving away from kerosene, as evidenced by the sharp decline in the share of rural households using kerosene as the main source of lighting energy from 70% in 2011/12 to 9% in 2017/18. A large proportion switched to off-grid solar (33%) or torches and rechargeable lamps (37%), while the share of households where lighting mainly comes from grid electricity increased merely from 4 to 10% in that period (URT 2013, 2019). This is far below the level in urban areas (64%), showing the clear urban-rural inequality when it comes to access to, and use of, grid electricity.

These meagre improvements in the adoption of grid electricity access come despite considerable efforts to extend rural electricity grids. These efforts have been streamlined with the establishment of the Rural Energy Agency (REA) in 2008 as an autonomous body under the Ministry of Energy. The REA's annual budget increased in real terms 50 times to US\$239 million in 2016–17 (Godinho and Eberhard 2018). There are several challenges to promoting access to grid electricity in rural Tanzania. Firstly, rural Tanzania has a low population density and is marked by sparse settlements. This attenuates the financial sustainability of infrastructure investments such as the extension of the national electricity grid. Secondly, regulated tariff rates are below the cost of generation, also considering the substantial transmission losses of 25% (Gregory and Sovacool 2019). This makes connecting households to the electricity grid a loss-making venture for the utility. Third, even in electrified villages, household connection rates remain low. The Government of Tanzania estimates that 49% of the rural population resides close enough to electricity lines to not require an additional electricity pole, which often makes connection costs prohibitive for households (URT 2017).

3. Methodology

3.1 The Data

The data used in this study was collected in a large cluster in Mpwapwa district of Dodoma region in central Tanzania, a region where the rural electricity connection rate is identical to the national rural connection average (URT 2017). This cluster includes all 43 electrified sub-villages (hamlets) from 24 villages in a radius of 35 kilometers around the district office of the para-statal electricity utility company, TANESCO. The TANESCO district office served as a reference because technicians are sent from these offices when prospective customers request an electricity connection. The 35 km threshold ensured that there were no supply side restrictions on electrification. TANESCO confirmed being able to reach villages within this radius easily, whereas it sometimes faces difficulties with requests from more remote places. This is due to poor rural road conditions and insufficiency of physical and human resources. The sub-villages were all electrified in the context of the rural electrification schemes of the REA, REA I to REA III.

The survey was conducted at household level, with complementary data collected at sub-village level. The study population comprised households living within reach of the electricity grid. After consultation with TANESCO, we defined households living at most 60 meters from the nearest electricity pole as ‘within reach of the grid’. Those living farther away need to pay for additional poles which generally makes it prohibitive for individual households to connect. Sampling in this corridor used a census of non-connected households, which had been conducted for a prospective field experiment that was intended to focus at interventions among non-connected households. Sampled non-connected households had to meet a precondition for connection that the utility TANESCO imposes for safety reasons: their roof have to be made of iron sheets. We also applied this criterion in our sampling so that we could better understand what other factors drive the low uptake of electricity, conditional on meeting the required criteria.¹ Connected households were additionally and randomly sampled during the census exercise, by a ratio of 1:4 or 1:5, depending on the sub-village size. Data collection took place in August 2019.

After using GPS data to verify that non-connected households in the sample live within the 60-meters threshold, our final sample comprises 1774 households, of which 259 are connected. The actual proportion of grid-connected households, according to data provided by sub-village representatives, in our ‘under the grid’ sample is on average 55%.

3.2 Estimation Strategy

We estimate two types of econometric models to study the demand factor correlates of electricity uptake using our survey data. First, we use a binary logit model, where household electricity access is regressed on a comprehensive set of predictor variables:

$$Y_{ij} = X_{ij}\beta + u_{ij} \quad (1).$$

Y_{ij} is an indicator of connection to the electricity grid of household i in sub-village j . and takes the value 1 if household is connected to the electricity grid, otherwise 0. β is the vector of coefficients of interest and u_{ij} is the error term assuming logistic distribution of the error term. X_{ij} is a vector

¹ With the increased adoption of modern roofing (URT 2019), this structural requirement no longer represents the strong barrier to connection that it was a few years earlier (cf. Ahlborg and Hammar 2014).

of explanatory variables listed in Table 1, including socio-economic characteristics, social network and housing characteristics, as well as geo-referenced distance from the sampled households to nearby electricity poles and to the nearest TANESCO district office (introduced above). These variables have been selected to assess their different roles played in the uptake of modern energy sources as articulated in the literature. The variables additionally have been chosen for being plausibly unaffected by an electricity connection in order to avoid confounding through an effect of the electricity connection outcome on these explanatory variables.

Second, we adopt a multinomial logit model (MNL), given that MNL allows the analysis of decisions across more than two types of energy sources. This is to account for the strong increase in decentralized electricity sources in rural Tanzania even among households residing close to electricity poles. In our case, the response variable Y_{ij} includes three distinct main lighting energy alternatives k : electricity from the central grid, decentralized electricity (i.e. solar energy with solar home systems or other electricity source) and non-electricity sources (i.e., kerosene, candle and dry cell battery light). Accordingly, the MNL model can be specified as follows:

$$Prob(Y_{ij} = l) = \frac{\exp(X_{ij}\beta_l)}{\sum_{k=0}^2 \exp(X_{ij}\beta_k)} \quad (2)$$

where l is the light energy source chosen by household i from sub-village j . X_i is the same vector of explanatory variables as in equation (1). In different specifications, we use either non-electricity energy sources or decentralized electricity as the reference category, taking on the value of $k=0$. Thus, β_l represents the vector of estimated coefficients for each of the two alternative lighting energy sources l , respectively. The results of the MNL model are interpreted in terms of relative risk ratios, i.e., the probability of choosing one outcome category divided by the probability of choosing the reference category (Bensch et al. 2018; Rahut et al. 2017).

Accordingly, a parameter above (below) 1 indicates that the probability of choosing grid electricity is higher (lower) than the probability of remaining with the reference electricity source, either non-electricity energy sources or decentralized electricity.

4. Results

4.1 Descriptive Statistics

Table 1 presents descriptive statistics of our sampled households, differentiated by connection status. We show three sets of explanatory variables in Panel A to C to underscore different roles played by each of these sets of factors on the uptake of modern energy sources as articulated in the literature. Panel D shows descriptive statistics on the dependent variable, electricity access.

Panel A presents housing and geographic characteristics of our sampled households. Notably, connected households have bigger houses which are more often made of more modern wall material according to simple bivariate t -tests on equality in means. The average distance from the nearest TANESCO office is 21 km.

The average respondent age and household size shown in Panel B are consistent with the official population census. Only 12% of respondents are engaged in off-farm activities. All socio-economic variables, except age of household head, show significant differences between households with grid electricity and households without the connection. For example, the average daily expenditure on basic needs over the past month, as a proxy for income, suggests that connected households are relatively richer (TZS 8,100 or USD 3.5 per day) than non-connected households (TZS 5,700 or USD 2.5 per day).

We present variables related to social networks in Panel C, as the literature asserts that the decision to adopt a new technology could be influenced by the adoption decisions of the household's network of family and friends (see for example Bandiera and Rasul 2006, Conley and Udry 2010, and Beaman et al. 2021). We measure the extent of social networks by a number of variables, including years lived in the village, number of relatives and friends connected to electricity both within and outside the village, and the amount of cash transfers (remittances in TZS value) received by the households from relatives or friends living outside the village (which is obviously also a measure of ability to pay). The number of friends and relatives who are connected to electricity and the value of remittances that households receive both show significant variations between households with and without grid electricity.

Table 1: Descriptive Statistics

Variable description	Connected Households		Non-connected Households		Connected vs. non-connected
	mean	sd	mean	sd	<i>p</i> -value
Panel A: Housing and geographic characteristics					
Housing wall is made of brick/stone/cement	0.69		0.47		0.00***
House is privately owned	0.97		0.93		0.03**
Number of rooms in the house	4.15	1.39	3.47	1.04	0.00***
Distance from the nearest electric pole, in meters (GPS measured)	20.87	10.75	25.02	13.21	0.00***
Distance to the district TANESCO offices, in kms	21.14	14.96	20.55	14.52	0.55
Panel B: Demographic and socio-economic factors					
Age of respondent	44.20	12.60	45.83	16.24	0.13
Respondent is male	0.78		0.66		0.00***
Respondent is married living with spouse	0.88		0.70		0.00***
Respondent completed primary education	0.75		0.66		0.00***
Respondent is employed or running own business	0.18		0.11		0.00***
Household size	5.60	2.13	4.68	2.08	0.00***
Monthly family expenditure on basic needs, in TZS	8,100	17,200	5,700	17,300	0.04**
Any household member owns a bank account	0.11		0.05		0.00***
Panel C: Social network related factors					
Number of years lived in the village	17.07	13.38	15.75	14.59	0.17
Number of closest neighbours connected to electricity	2.35	2.20	2.15	1.83	0.12
Number of friends/relatives connected to electricity within the village	3.51	5.08	2.52	3.21	0.00***
Amount of remittance received from friends/relatives within past 6 months, in TZS	29,000	68,000	20,100	57,000	0.02**
Panel D: Electricity access					
Main source of lighting energy					
kerosene, candle or dry-cell battery	0.04		0.74		0.00***
individual solar home system (or other electricity source)	0.01		0.25		0.00***
grid electricity	0.95		0.00		0.00***
Number of observations	259		1515		1774

*Note: p-values refer to two-sided t-test on equality in means between connected and non-connected households. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$*

Finally, Panel D makes it clear that for virtually all connected households, grid electricity is also their main energy source of lighting. At the same time, 25% of non-connected households have an alternative decentralized electricity source at their disposal (mainly solar panels) and 74% rely on traditional sources of light (i.e. kerosene, candles, and dry-cell batteries).

These results already suggest that social and economic differences correlate to some degree with the uptake of electricity in rural Tanzania. These findings are analysed in greater detail in the following section.

4.2 Estimation results

Table 2 presents the results from the binary logit model estimation, expressed as marginal effects. In column (1), we show the estimation results on the determinants of connection for a parsimonious model that only controls for five housing and geographic characteristics falling under Panel A of Table 1. Adding further controls enables us to assess other relevant correlates of the electricity connection in rural Tanzania.

The results suggest that households located farther from the nearest electric pole are somewhat less likely to have their houses connected to grid electricity even under the current restriction of 60 meters radius. Specifically, an extra ten meters from the electric pole reduces the likelihood of connection by 3 percentage points, other factors held constant. On the other hand, distance from the TANESCO office has no association with choosing to connect to grid electricity, which supports the notion that the sampled villages are sufficiently close to that office for being served when interested in a household connection. Housing characteristics as measured by the number of rooms and walling materials are robust predictors of connection status. Households with bigger houses and those with strong walling structures (i.e. brick, cement or stone walls) are more likely than their counterparts to be connected to grid electricity. While wall characteristics could put an indirect physical constraint on connection (e.g. through the convenience of house wiring), we believe that the mechanism through which housing size could influence connection is primarily as another proxy for household's ability to pay.

We present the estimation results for the broader set of potential correlates of connection in column (2). Coefficients for the housing and geographic characteristics remain largely unchanged. Beyond that, we find that relatively older household heads are less likely than their younger counterparts to have their houses connected to grid electricity, all else equal. However, the relationship is different when it comes to the married respondents living with their partners,

suggesting that having a stable family is more likely to increase the demand for electricity compared to those living alone (i.e. non-married or divorced), all else equal. When it comes to the role of social networks, we find that the more social connections one has is not associated with the household's decision to connect, all else equal. This also applies for the amount of remittances received from close relatives and friends.

Table 2: Binary Logit Estimates on Correlates of Connection

	Dependent variable: Coefficients:	grid electricity connection marginal effects	
		(1)	(2)
Housing wall is made of brick/stone/cement	0.101*** (0.016)	0.080*** (0.016)	
House is privately owned	0.051* (0.027)	0.038 (0.027)	
Number of rooms in the house	0.047*** (0.006)	0.036*** (0.006)	
Distance from the nearest electric pole, in meters	-0.003*** (0.001)	-0.003*** (0.001)	
Distance to the district TANESCO offices, in kms	0.000 (0.001)	0.000 (0.001)	
Age of respondent		-0.001** (0.001)	
Respondent is male		-0.010 (0.022)	
Respondent is married living with spouse		0.081*** (0.018)	
Respondent completed primary education		0.016 (0.016)	
Respondent is employed or running an own business		0.026 (0.025)	
Household size		0.009*** (0.003)	
Monthly family expenditure on basic needs, in TZS		0.000 (0.000)	
Any household member owns a bank account		0.053 (0.038)	
Number of years lived in the village		0.001** (0.001)	
Number of closest neighbours connected to electricity		-0.002 (0.005)	
Number of friends/relatives connected to electricity within the village		0.002 (0.002)	
Remittance received from friends/relatives within past 6 months, in TZS		-0.000 (0.000)	
Observations	1774	1774	

Note: Coefficient estimates show marginal effects. Robust standard errors in parentheses.

**** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$*

Interestingly, household average expenditure, which we use as a proxy for income, show no relationship with electricity connection. However, the number of years one has lived in the village is found to be associated with connection.

The multinomial logit model results can be taken from Table 3. The interpretation of the relative risk ratios (rrr) is in reference to the base category mentioned at the bottom of the table, either traditional, non-electricity lighting energy sources (i.e. kerosene, candles and dry-cell batteries) or decentralized, mainly solar energy sources, allowing us to understand potential drivers of choices of grid connection. We see that changes in the distance from an electric pole not only makes it less likely to be grid connected compared to relying on traditional lighting sources, but also compared to using solar sources. This implies that those farther from electric poles not only have a lower probability of connecting to grid electricity, but are also relatively more likely to use off-grid electric sources. These results are robust even after controlling for additional covariates as presented in columns (3) and (4). Consistent with previous results, we find that in most cases housing characteristics correlate significantly with the probability of using grid electricity over traditional lighting sources or over solar energy. On average, households with more rooms and households with walls made of brick, stone, or cement (as opposed to lower-cost traditional building materials) are more likely to opt for grid electricity rather than using kerosene/candles or solar energy as main lighting sources, all else equal. Again, these results are stable and robust when controlling for other covariates.

Looking deeper into the extended set of controls in columns (3) and (4), results confirm our previous results in that married families and households that have lived longer in the village are more likely to use grid electricity as opposed to the traditional sources, all else equal. Monthly family expenditure (as a proxy for income) does have a significant but economically minimal effect on the likelihood of connection to grid electricity. The number of friends/relatives connected to grid electricity within the village does not increase the likelihood of using a connection to the grid as opposed to traditional energy sources or solar energy sources.

We find for none of the assessed variables that the relative risk ratio is above one with traditional energy sources as the reference category and below one with solar as the reference category, or

vice versa. The results in Table 3 are very consistent with those presented in Table 2, suggesting that the choice of any given lighting source, including the uptake of REA electricity, is not random but rather influenced by a set of parameters.

Table 3: Multinomial Logit Estimates on Correlates of Lighting Energy Choices

Dependent variable: Coefficients:	grid electricity connection relative risk ratio (rrr)			
	(1)	(2)	(3)	(4)
Housing wall is made of brick/stone/cement	3.003*** (0.467)	1.922*** (0.336)	2.535*** (0.428)	1.879*** (0.354)
House is privately owned	2.044* (0.852)	1.769 (0.788)	1.794 (0.734)	1.535 (0.690)
Number of rooms in the house	1.859*** (0.134)	1.232*** (0.075)	1.758*** (0.141)	1.190** (0.080)
Distance from the nearest electric pole, in meters	0.975*** (0.005)	0.965*** (0.006)	0.974*** (0.006)	0.965*** (0.006)
Distance to the district TANESCO offices, in kms	1.003 (0.006)	0.991 (0.006)	1.005 (0.007)	0.995 (0.007)
Age of respondent			0.977*** (0.007)	0.991 (0.008)
Respondent is male			0.913 (0.217)	0.940 (0.247)
Respondent is married living with spouse			3.474*** (0.963)	1.844** (0.563)
Respondent completed primary education			1.313 (0.238)	1.103 (0.223)
Respondent is employed or running an own business			1.634** (0.384)	1.221 (0.302)
Household size			1.085** (0.041)	1.045 (0.042)
Monthly family expenditure on basic needs, in TZS			1.000** (0.000)	1.000 (0.000)
Any household member owns a bank account			1.682 (0.538)	1.336 (0.422)
Number of years lived in the village			1.021*** (0.007)	1.017** (0.008)
Number of closest neighbours connected to electricity			0.970 (0.050)	1.006 (0.052)
Number of friends/relatives connec- ted to electricity within the village			1.049* (0.027)	1.003 (0.024)
Remittance received from friends/ relatives within past 6 months, in TZS			1.000 (0.000)	1.000 (0.000)
Observations	1774	1774	1774	1774
Reference category	traditional	decentra- lized	traditional	decentra- lized

Note: Coefficient estimates show marginal effects. Robust standard errors in parentheses.

**** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$*

5. Discussion and Conclusion

In recent years, the Tanzanian government policy has been committed to extending electricity to rural villages and providing connection subsidies. Despite these efforts, the rate of grid connection has been very low. As we see in our analysis, despite the high level of subsidies for grid connections, household wealth status still seems to contribute significantly to the decision at household level whether or not to connect. This could partly be because wealthier households are more likely to be able afford not only the connection cost but also the subsequent purchase of electric appliances (e.g. radio, television, etc.), something that could act as a motivating factor. Discussions with different stakeholders suggested that in-house wiring poses an additional deterrent. We therefore also asked households about their spendings on in-house wiring, and indeed these costs paid to technicians were on average about eight times higher the grid connection costs paid to the utility for the wiring and equipment that connects the house to the local low-voltage distribution grid. Future research could look at this cost factor to see how much of a barrier it is to household electricity uptake.

Our study also looked into the energy transition from traditional energy sources via decentralized solutions to grid electricity. Notably, we see high shares of individual solar energy of about 25% even in our study sample that was specifically sampled from households living within reach of the electricity grid. At least partly, this may reflect a shift of user preferences from on-grid to smaller and cheaper off-grid technologies, adding insights into the policy debate on on- versus off-grid solutions (Peters and Sievert 2016). In this context, we furthermore find that the mechanisms that lead households to choose electricity over traditional energy sources seem to work in a similar way when it comes to choosing between electricity and decentralised solutions such as individual solar energy sources.

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