

Why is Household Electricity Uptake Low in Sub-Saharan Africa?*

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Abstract

Access to electricity in Sub-Saharan Africa is the lowest in the world, although a larger proportion of the population lives under the grid. This demand-side challenge is likely to be exacerbated with the grid expansion as the areas currently off-grid are disproportionately more rural and poorer. This paper uses the most recent individual and household level data to examine the determinants of, and barriers to, electricity uptake in Sub-Saharan Africa. It supplements the analysis with qualitative fieldwork in three countries. Regarding the areas under the electricity grid, the paper follows Wodon et al. (2009) to show that demand-side constraints to a large extent explain the low level of electricity access and then proceed to identify the factors that drive uptake both at an individual and community level. Findings suggest that while the level of income remains a primary and consistent driver of uptake, regularity and predictability of income is a key constraint. Additionally, housing quality, independently of the variation in their socio-economic status is a significant determinant of uptake. To extrapolate on the determinant of uptake in areas currently off-grid, shall the grid be extended to those areas, we use Heckman (1976) two stages estimation procedure and several control variables to address selection bias. The analysis reveals that targeting communities that already enjoy higher economic livelihood or communities in which the provision of electrification is likely to induce economic activities is key to achieving high take-up rates and contribute toward the financial viability of the utilities and the sector. Policies such as pre-paid meters, energy-efficient appliance, credit access would address some of the specific constraints. However, the desire for productive use emerging from the qualitative work suggests that electrification efforts may be more successful if bundled with facilities for household to acquire appliances for productive use which has the potential to increase uptake and enhance livelihoods simultaneously.

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1 Introduction

About one-third of the population in Sub-Saharan Africa has access to electricity, although various estimates indicate that a more significant share of the population lives under the grid ranging from 61 percent (Demographic and Health Surveys data) to 78 percent (Afrobarometer). Take-up rates (i.e., the share of the household living under the electricity grid who are connected) are high in a few countries (South Africa, Nigeria, Gabon, and Cameroon), and they are deficient and often below 50 percent in other countries (Malawi, Liberia, Uganda, Niger, and Sierra Leone). There is also within-country variation in take-up rates, with a high concentration around big cities and urban centers. Low take-up is an essential issue for understanding the demand side of electricity, especially given that most off-grid communities are rural and more impoverished hence, *ceteris paribus*, take-up rates would be even lower in such areas if they were covered. This situation underscores the need for a deeper understanding of the constraints on the demand side and the incentives for take-up. To make electricity expansion financially viable, and to incentivize private sector participation in the sector, take-up rates need to be higher.

Many studies have examined the supply-side issues that are behind the dismaying statistics on access, focusing on the multifaceted causes of under-investment and poor energy sector performance (see Rosnes and Shkaratan (2011) for extensive analysis). The geographic concentration of energy resources, inefficient size of countries power systems, poor institutional, the regulatory and technical capacity of African power sectors, poor utility performance, other investment climate issues and need for regional integration are among the leading supply-side factors discussed in the literature. Significant supply constraints need undoubtedly to be addressed as many African countries just do not have enough electricity to distribute to potential consumers. The region's entire installed capacity is a little over 80 GW, of which 45 GW is in South Africa alone.

Addressing the supply-side constraints must go hand in hand with a better understanding of the issues on the demand-side. As stated before, it is a fact that even where service is available, people may still not connect. However, less is understood of the reasons why. An extensive analysis of demand-side barriers to access, assessing both affordability issues and preferences for alternatives, was conducted by (Banerjee et al., 2008) as

part of the World Bank’s Africa Infrastructure Country Diagnostic Study (AICD, 2010). The study used a pool of household surveys spanning 32 SSA countries and a period of 15 years to analyze the affordability of monthly bills. The study inferred that difference between availability of grid and access remains high among African households, with them choosing not to connect. They can afford modest monthly bills priced at levels compatible with recovery of operating costs by the service provider. Nevertheless, around 60 percent of the African population cannot afford to pay full cost recovery tariffs or extend consumption beyond the absolute minimum subsistence level.

In addition to the monthly bill, a critical demand-side constraint is an ability to pay the upfront connection fees. The charges can range from very modest and often subsidized sums of \$10 - \$20, to close to \$200 and more in some countries. Compared to gross national income per capita, the connection charges can be higher, as evidenced in Burkina Faso, Central African Republic, Kenya, Tanzania, and Rwanda. Out of all the regions in the world for which information is available, Sub-Saharan Africa has the highest number of countries with connection charges above \$100 per customer and correspondingly low rates of electrification (Golumbeanu and Barnes, 2013). A recent study in ten countries provided additional stylized facts about the total upfront connection fees, including all transaction cost, showing among other things that they present many variations and may be implicitly regressive Blimpo et al. (2017a). While on the surface these charges may appear to be a low hanging fruit policy instruments, a recent analysis that considered equilibrium effects simultaneously from the consumer, utilities, and regulators perspectives, shows that high upfront connection charges are instead symptoms of deep-rooted issues in the sector, including the tariff structure and the low consumption levels Blimpo et al. (2017b).

A comprehensive analysis of this phenomenon of ”under the grid” and ”connection charge” constraint has been carried out in Kenya since 2012 by a team of researchers from the University of California, Berkeley and Innovations for Poverty Action. Using a novel data set of 20,000 geo-tagged structures in 150 communities in rural Western Kenya where huge capital investments in grid infrastructure have been made over the years, they found that electrification rates remain very low including for relatively well-off households. The connection cost of \$400 has emerged as a significant barrier for households to pay upfront. In an experimental design, the researchers offered various levels of connection fees

to the treatment group in sample households, ranging from \$0 to \$171 and \$284 and left the control group with \$398. They found that while take-up is almost universal at \$0, it is still relatively low at \$171 suggesting that credit constraints need to be consistently lowered for Kenya to reap the benefits of existing infrastructure (Lee et al., 2014). In 2015, Kenya had adopted the "last mile electrification" as a flagship program with the financial support of World Bank and African Development Bank and had lowered the connection fees to 15000 Ksh (\$171).

The example of Kenya highlights the growing need to understand the demand side barriers. Massive rural electrification resulted in take-up rates as low as 5 percent indicating a dramatic waste of resources. Similarly, in Uganda, a recent rural electrification program reported about 17% take up rate. On the other hand, in Nigeria, the take-up rate is exceptionally high, even though the reliability of electricity remains a huge problem and only 5% of households connected to the grid report having electricity all the time. On average, in Sub-Saharan Africa, the average take up rate in areas covered by the grid is often far from 100% and varies significantly by country. Low access rates indicate supply-side problems; while low take up rates point to demand-side barriers to access. Affordability is indeed a significant constraint, especially among credit constraint households. It remains unclear though if lowering the connection fees and tariffs are sufficient to induce households to connect to electricity. The evidence from the study in Kenya does not seem to confirm the affordability hypothesis as a primary or sole factor at play. Moreover, for the very few countries for which panel data is available, we observe a small percentage of households that decide to disconnect from electricity. A recent report issued by the Center for Global Development stresses the need to define what access to modern energy means Energy Access Targets Working Group (2017). The current definition is at a level that is required to light up one light bulb for five hours a day and charge a cell phone. To correctly pin down the definition of access to modern energy, we need to understand better what households use energy for. Moreover, since the demand for electricity is directly related to the appliances households use when connected to the grid, the cost of acquisition of such appliances is an indirect cost of connection. It is unclear if a household will carry on the burden of connection fees if it cannot afford to purchase desired appliances. Therefore, the actual cost of connection to a household is more complicated than what has been recognized so far in the literature. Moreover, assessing the

cost of electricity requires knowing per unit cost of it. Often, relying on unit cost data presents us with an incorrect picture as many of the households do not have meters. In such cases, the rationale behind the bills is often unclear and can discourage households from connecting to the grid and introduces resistance to pay. In light of the results of previous studies documenting low take up rates, there are two complementary channels through which we can achieve the desired level of electrification in Africa. The first one is to incentive's households to connect to the grid in areas in which grid connection is already available. The second one is to expand the grid to areas that are currently unserved. In this paper, we will first restrict the analysis to areas currently covered by the grid, quantify the demand and supply side gaps and analyze household's decision to connect to the grid. We further expand the analysis to a community level to understand the projected connection rates in communities not covered by the grid.

Undeniably, the supply side of coverage deficit has not yet been resolved. A Large part of especially rural Africa remains without access to electricity. Expanding the grid to currently off-grid areas or coming up with cheap, innovative solutions is crucial to achieving universal access. However, our results show that even in areas that are currently covered by the grid, take up is well below 100% which implies that an incentive scheme is necessary for individuals to connect to the grid. Moreover, grid expansion should be implemented in a way that ensures high take up rates. Per our findings, economic well-being is crucial to ensure the latter. Considering these results and the high prevalence of poverty across Sub Saharan Africa electrification presents a considerable challenge.

The paper is organized as follows. Next section discusses the contextual background, and section 3 briefly delivers macro-level evidence. Section 4 proceeds with the analysis of barriers to electricity. Section 5 presents the analysis at a community level. Section 6 concludes.

2 Contextual background

The 2015 Energy Report stated that about 32% of individuals in Sub-Saharan Africa were connected to electricity (Bank and IEA, 2015). According to the World Development Indicators in 2012 this number increased to 35%¹. When discussing access to electricity three basic statistics are of interest. We will refer to coverage as the share of households

¹<http://data.worldbank.org/indicator/EG.ELC.ACCS.ZS>

located in PSU covered by the grid. We say that a PSU is under the grid if at least one household in this PSU is connected to (has access to) the grid. Electrification (or access rate) denotes the unconditional fraction of households connected to the grid while take up rate informs us about the share of households with access to electricity in areas covered by the grid. Using data from the most recent Afrobarometer, figure 1 illustrate electrification and take up for selected Sub-Saharan countries and reveal a great variation along the two measures both across the countries and within the countries between the urban and rural areas. Access rate varies between as low as 17% in Burundi to 99% in Cape Verde indicating a very different contextual landscape in different countries. Take up rates also vary greatly. While in Malawi only 1 in 4 households under the grid are connected, in South Africa and Gabon almost every household enjoys grid connection in the covered areas.

Quite a few countries enjoy high coverage rates but far below 100% take up rates. While the differences in coverage among countries point directly to vast differences in infrastructure development, the disparities among take up rates stress the significance of demand-side barriers to electricity. Cape Verde is the only country with very high coverage, and take-up resulting is over 90% of all households having a grid connection. In many other countries, even though the coverage is high, the take up rates remain relatively low implying that the lack of connection is not necessarily solely due to supply-side issues. In Swaziland, despite the 96% coverage, only 69% of all households are connected to the grid. 29% of households in areas under the grid opt out of the electrical connection. On the other hand, Nigeria has a 98% take up rate indicating that supply-side barriers are responsible for the lower electrification rates. Majority of Sub Saharan countries though are characterized by coverage below 80% indicating a substantial need for infrastructure development. In Burundi, one in every five households is in a covered area. In Burkina Faso, Niger, Sierra Leone, Mali, Liberia, Guinea, Madagascar, Uganda, Malawi, Mozambique, and Tanzania less than 50% of households are covered by the grid indicating that less than one in every two households has access to the grid. Out of the low access rates countries, only Guinea, Mali, Sierra Leone, and Mozambique have high take up rates (above 80%). On the other hand, in Burundi, Liberia, and Malawi only 10% or fewer of all households are connected to the grid.

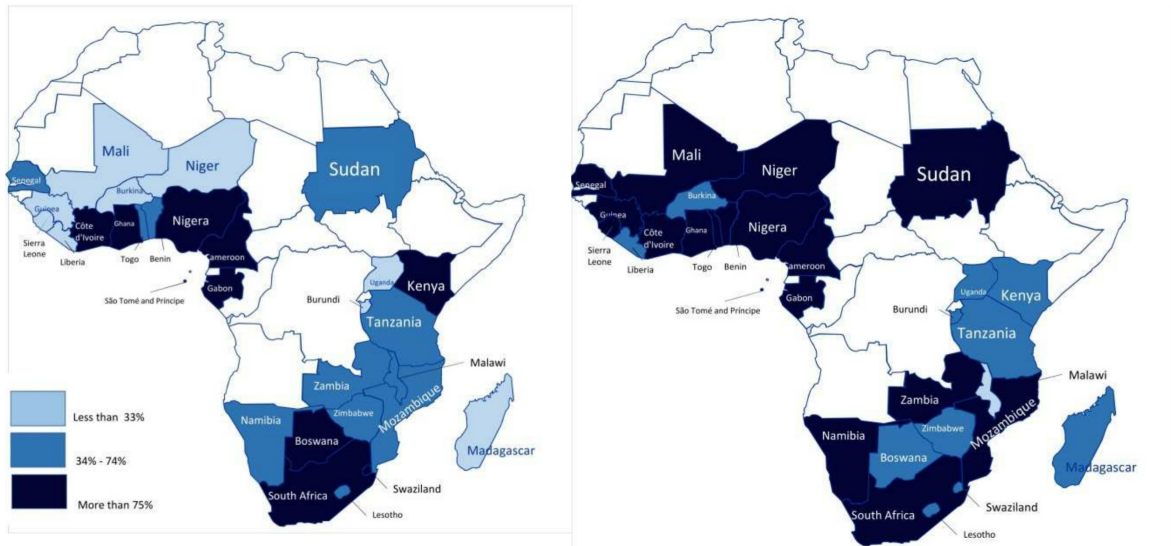


Figure 1: Coverage and take up in Sub Saharan Africa

While the disparities among countries regarding infrastructure development are to be expected, the disparities among the take up rates appear to be less straightforward. For example, in Kenya, despite the high coverage rate of 83%, only 40% of all households are connected to the grid. Conditional on areas being covered by the grid, on average, one in every two households is not connected to the grid. Out of countries where coverage does not appear to be a significant problem, Kenya has the lowest take up rates posing an interesting question why it is the case. If it is all due to affordability, then countries with similar per capita income should enjoy an equally low take up rates. Kenya's GDP per capita is about 2818 USD (in 2011 USD). Sao Tome and Principe and Cameroon are both characterized by high coverage rates like Kenya and have similar GDP per capita of 3030 USD and 2835 USD respectively. However, the take up rates in both countries are much higher than in Kenya. In Sao Tome and Principe 89% and Cameroon, 94% of households are connected to the grid in covered areas. This evidence is suggestive that there are other demand-side barriers to electricity access and that conventional grid expansions efforts might very well fail at achieving universal access to electricity. A recent study on Burkina Faso further confirms this conjecture by concluding that "the current grid extension is becoming inefficient and unsustainable to reach the national energy access targets" (Moner-Girona et al., 2016). Authors suggest that mini-grids powered by local renewable energy sources are more successful in connecting more people to electricity than standard grid expansion. Splitting the sample into rural and urban areas reveals that

rural areas are at a more considerable disadvantage regarding grid coverage as illustrated in figure 2. Apart from Liberia, all other countries enjoy at least 70% coverage in urban areas. In the rural areas, only seven countries in our sample enjoy the equally high coverage. Rural Sub Saharan Africa, apart from Cape Verde, Swaziland, South Africa, Botswana, Cameroon, Nigeria remains broadly without grid coverage.

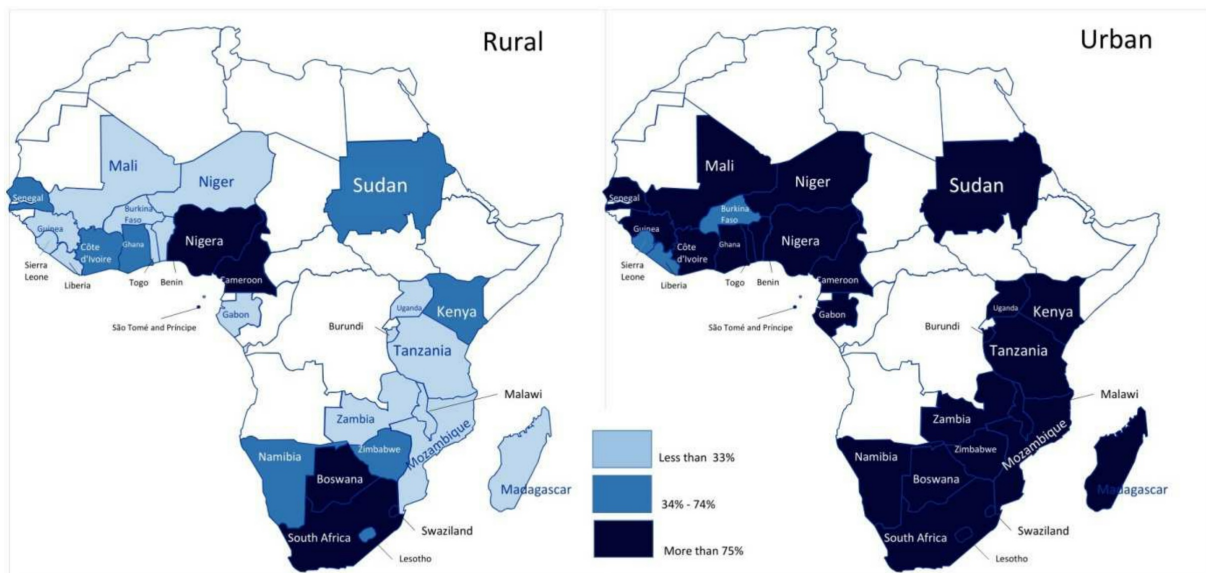


Figure 2: Access to electricity rates in urban and rural areas

Given the dramatic difference regarding urban and rural electrification it should come as no surprise that comparison of the areas covered by the grid to areas without access to the main grid shows vast differences regarding infrastructure indicating that areas under the grid enjoy better access to infrastructure as presented in table 1. 61% of areas covered by the grid are urban, and 93% of off-grid areas are rural. It is only access to schools and cell phones is widespread in both off-grid and under the grid areas. Areas covered by the grid are about three times as likely to have access to piped water, paved roads and police station as areas off the grid. Sewage systems, banks and post offices, if present at all, are almost inevitably in areas under the grid. Even access to a clinic is more widespread in areas under the grid as 66% of those areas have a health center within walking distance. Only 42% of areas off grid enjoy such service. Access to public transport is also easier accessible in areas under the grid.

Table 1: Comparison between communities under the grid and off grid

	Under the grid	Off grid
Rural	0.39	0.93
Access to piped water	0.79	0.23
Sewage	0.44	0.01
Cell phone reception	0.97	0.81
Presence of paved roads	0.66	0.26
Post office	0.3	0.04
School	0.89	0.82
Police	0.46	0.14
Clinic	0.66	0.42
Market	0.77	0.47
Bank	0.35	0.05
Transport	0.93	0.64

Restricting the analysis to households in areas covered by the grid and comparison of households connected and not connected to electricity reveals equally stark differences as shown in table 2. First, the probability of connection appears to increase with the overall take up rate in the close neighborhood of the household. Given that average connection rate is a good proxy for the cost of connection as well as the socioeconomic status of the area; strong positive correlation is to be expected.

Households connected to electricity are more likely to have better socioeconomic status as measured by the wealth index². The observed differences are smaller than one would expect though. The wealth index composes of several binary indicators of household wealth and status³. Two types of variables are included in the index: indicators of housing quality and self-perceived economic well-being. The first category includes the type of the dwelling (house versus others), whether the household has a latrine and access to piped water and indicators of ownership of durable goods (TV, radio, motor, and phone). The second component includes indicators of self-perceived economic situation such as household economic situation (good versus bad), household economic situation in comparison to neighbors (better versus at least as good or worse), incidence of household being without cash (at most several times versus many times or always), country economic prospects (promising versus at most no change) and receiving of remittances (any versus none).

²The choice of using an index instead of its components as separate variables is driven by the high collinearity of the variables capturing the household wealth and socioeconomic status.

³We transform all variables into 0-1 variables and then take an average for each household.

Individuals living in connected dwellings are more than twice as likely to complete secondary schooling. They are also significantly more likely to hold a job that pays cash income and is employed in private sector or government organization. They are also less likely to be unemployed and self-employed. Overall, individuals in connected households appear to be more likely to have a stable employment with a guaranteed cash income. They also live in higher quality dwellings such as regular houses with better quality roofs, with access to piped water and latrines inside of the dwellings.

Looking at the community level characteristics, it appears that access to other services such as piped water and sewage increases the probability of a household connecting to the grid. Presence of a bank, police station and post office also positively correlates with the probability of connection. Access to the bank could imply easier access to credit and therefore help households cover the connection fees expenses and allow them to purchase appliances. Presence of a post office can also reduce the cost if contracts can be sent by mail. Presence of police station in the neighborhood might decrease the instance of illegal connections.

So far, we have classified households based on a simple binary connection indicator. However, defining access to modern electricity should incorporate the aspect of reliability of electricity. If a household experiences often and long-lasting blackouts, should we consider it as having access?

Figure 3 shows a dramatic variation across countries regarding the reliability of grid electricity. In Liberia, over 50% of connected households report that they never have electricity. In Sierra Leone, Uganda, Malawi, Mozambique and Niger all appear to have severe reliability problem with over or close to 30% of connected households reporting never having electricity. Cameroon, Tanzania, Ghana, Burundi, Uganda, Zimbabwe, Sierra Leone, Nigeria, Liberia, and Guinea all have over 50% of connected households with electricity available at most half of the time. On the other hand, Mali, Cape Verde, Gabon, Cote d'Ivoire, Swaziland, South Africa all appear to have a relatively reliable supply of electricity with at least 80% of households having access at least most of the time.

Table 2: Comparison between connected and not connected households in communities under the grid

	Not connected		Connected	
% connected in PSU	0.35	(0.29)	0.91	(0.17)
Rural	0.67	(0.47)	0.33	(0.47)
Household size	3.52	(2.14)	3.94	(2.34)
Age	37.38	(14.53)	35.37	(13.56)
Female	0.52	(0.50)	0.5	(0.50)
<i>Wealth quintile</i>				
1	0.36	(0.48)	0.25	(0.43)
2	0.2	(0.40)	0.2	(0.40)
3	0.2	(0.40)	0.21	(0.40)
4	0.14	(0.35)	0.17	(0.38)
5	0.11	(0.31)	0.17	(0.38)
Secondary edu	0.21	(0.41)	0.46	(0.50)
Job Paying Cash	0.21	(0.41)	0.33	(0.47)
<i>Employment type</i>				
Unemployed	0.33	(0.47)	0.32	(0.47)
Self Employed	0.48	(0.50)	0.35	(0.48)
Government/Private Sector	0.2	(0.39)	0.33	(0.47)
High quality roof	0.76	(0.43)	0.93	(0.26)
Water in the dwelling	0.05	(0.21)	0.34	(0.47)
Toilet in the dwelling	0.1	(0.29)	0.39	(0.49)
House vs other dwelling type	0.62	(0.48)	0.7	(0.46)
Own household doing well	0.23	(0.42)	0.36	(0.48)
Doing well in comparison	0.53	(0.5)	0.71	(0.45)
Future of country positively	0.13	(0.34)	0.16	(0.36)
Households is often w/o cash	0.49	(0.50)	0.3	(0.46)
Remittances received	0.15	(0.35)	0.24	(0.42)
<i>Community amenities</i>				
Piped water	0.55	(0.50)	0.84	(0.37)
Sewage	0.14	(0.35)	0.49	(0.5)
Cell	0.96	(0.20)	0.98	(0.16)
Post office	0.23	(0.42)	0.32	(0.47)
School	0.91	(0.29)	0.9	(0.29)
Police	0.39	(0.49)	0.5	(0.5)
Clinic	0.65	(0.48)	0.69	(0.46)
Market	0.78	(0.41)	0.79	(0.41)
Transport	0.91	(0.29)	0.94	(0.25)
Observations	6,036		22,712	

Standard deviations in brackets.

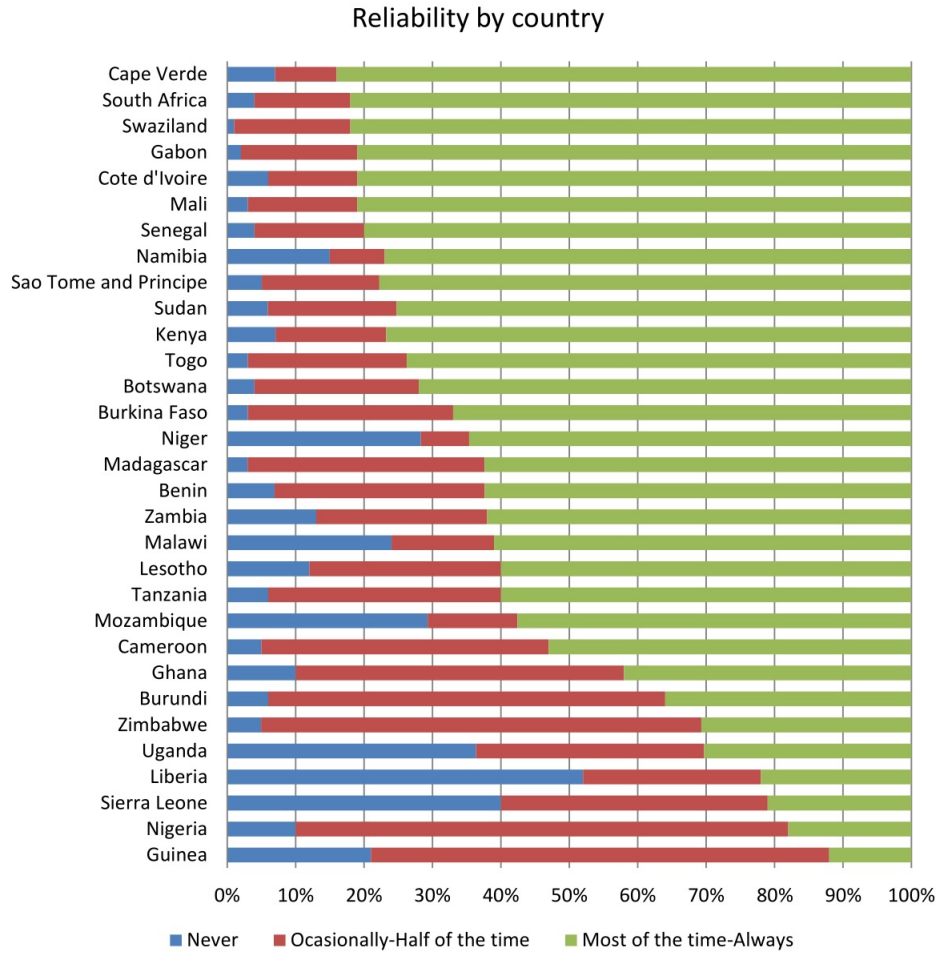


Figure 3: Reliability of grid electricity in connected households in Sub Saharan Africa

Nigeria represents a stark example. While it enjoys almost 100% coverage rate, which would deceptively leave us thinking that the goal of universal electrification, at least in the urban areas, has been achieved in Nigeria, less than 50% of the households report having electricity at least most of the time. 51% of households reported having electricity occasionally in the dwelling. It remains an open question whether such households should be classified as households with access to modern energy. Another issue which is not captured by the data at hand but which became apparent during the field work in Nigeria is the voltage available. The electricity available to households might be sufficient to light up a low voltage light bulb but is not enough to power a fan or a refrigerator. Reliability issues in the community can affect household's decision to connect to electricity through two channels. Service disruptions and low voltage lead to lower benefits of such service as well as constraints its productive use reducing household ability to pay for the

service. Indeed, there appears to be a strong and positive correlation between households connection rate and reliability of electricity as demonstrated in figure 4. For robustness, in addition to Aforbarometer data, we also use data from Global Tracking Framework (GTF), and the result remains.

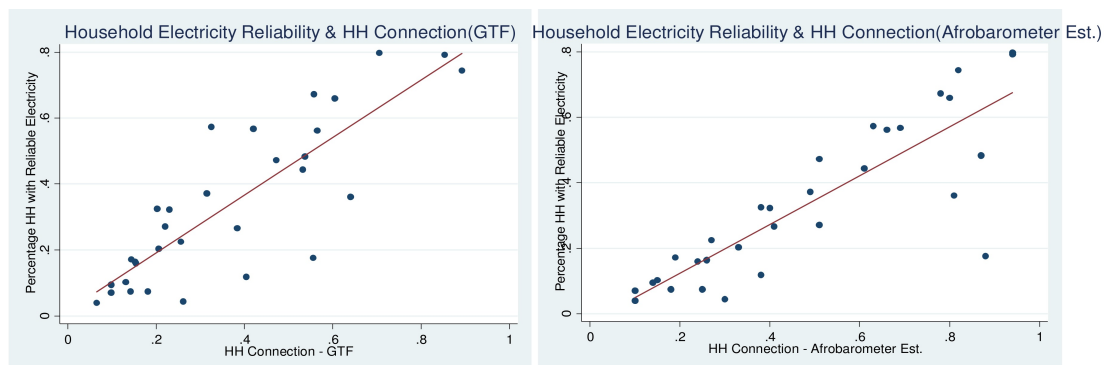


Figure 4: Household connection rates and reliability of electricity

Regardless of the definition of access to energy we adopt, it remains a fact that take up rates often lag far behind coverage indicating that demand-side barriers play a significant role. Perception of how difficult it is to obtain household services can be a significant deterrent of why households do not connect. Indeed, 56% of surveyed individuals who live in dwellings connected to electricity think that obtaining services is easy while only 43% of individuals who live in dwellings without electricity share this opinion (figure 5). If we restrict the sample to households that are connected to piped water, this difference disappears. That implies that the perception of how difficult it is to obtain services is biased towards more difficult and that certainly can affect take up rates.

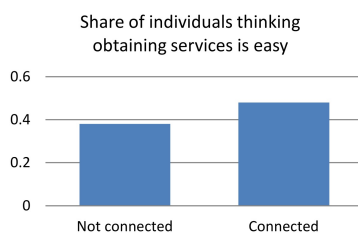


Figure 5: Perception of easiness of obtaining household services by connection status

3 Macro level evidence

Before turning to the analysis at a household and community level, let us first briefly summarize some trends observed at a macro level. Figure 6 summarizes the correlations

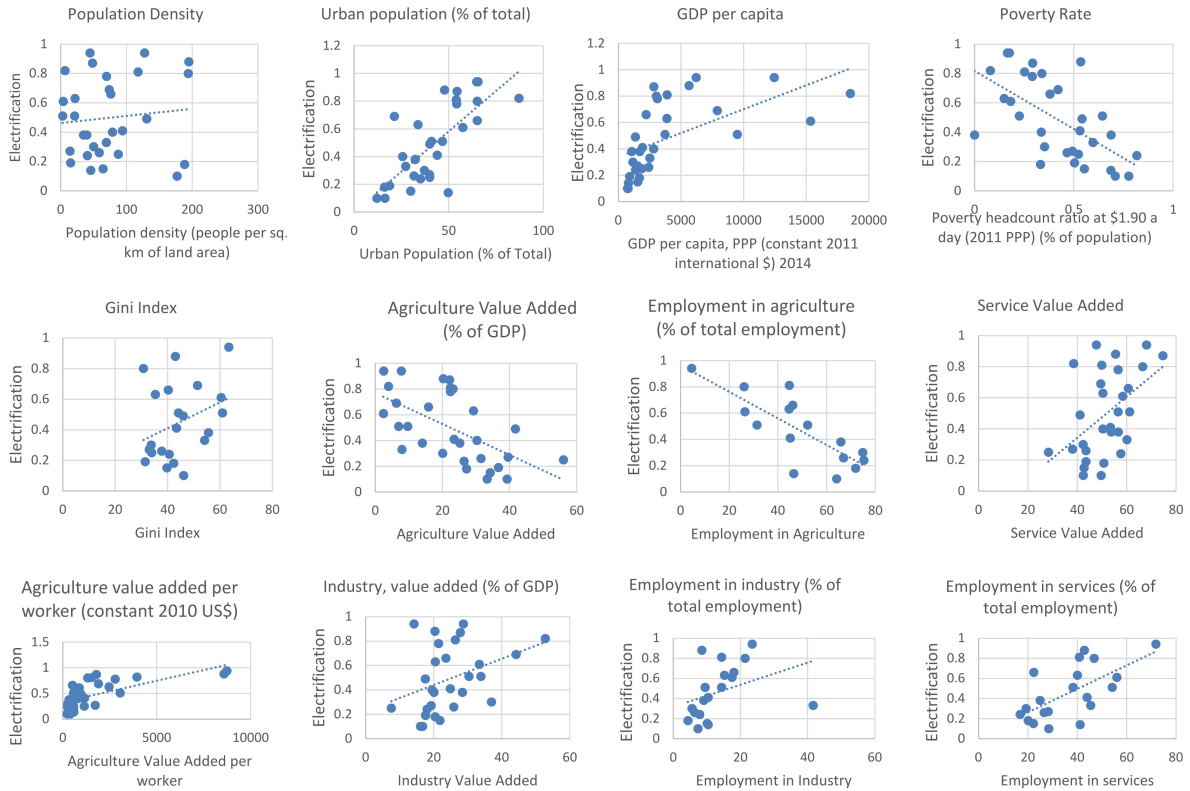


Figure 6: Electrification and macro indicators

of interests. Electrification appears to be most successful in densely populated countries with a high share of the population residing in urban areas and low poverty rates. GDP per capita, as well as Gini index, positively correlates with electrification. While the share of agriculture in GDP and employment in agriculture negatively correlate with electrification, countries with higher agriculture value added per worker are characterized by higher electrification rates. Both employment in industry and services, as well as a share of industry or services in GDP, exhibit a strong, positive correlation with electrification.

The somewhat surprising positive relationship between electrification and Gini index can be explained by the positive correlation between Gini index and urbanization which in turn correlates positively with electrification. Moreover, the correlation between Gini index and take up rate is negative over most of the values of the Gini index as figure 7. That implies that in countries with higher level of inequality the average take up rates are lower except for South Africa, Namibia, and Botswana. This fact further suggests that the correlation between electrification and Gini index is spurious.

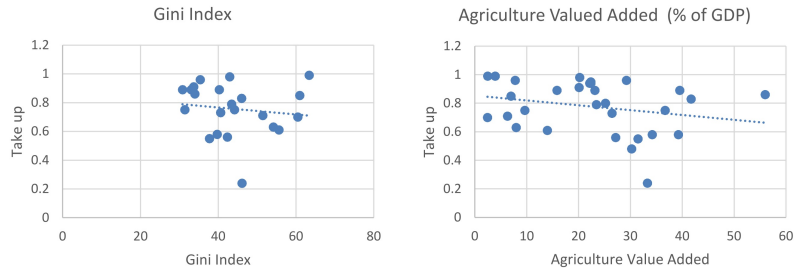


Figure 7: Take up and selected macro indicators

We now turn to the analysis of the barriers to access. Next section of the paper aims to analyze the probability of connection and further decompose the gap in coverage to demand and supply gap.

4 Analysis of barriers to access

4.1 Data landscape and methodology brief

We proceed with Afrobarometer data to more rigorously analyze the characteristics of households connected to the grid⁴. As a robustness check, we compare access rates obtained from Afrobarometer to the access rates obtained from 2012 World Development Indicators (figure 8). The correlation between the two series is 0.832 which is rather high given the differences between the two measures. In Afrobarometer we define access as the percentage of households connected to the grid whereas in WDI it is the percentage of individuals that have electricity in their homes regardless of the source (WBG, 2012).

⁴Forthcoming is the analysis using LSMS surveys.

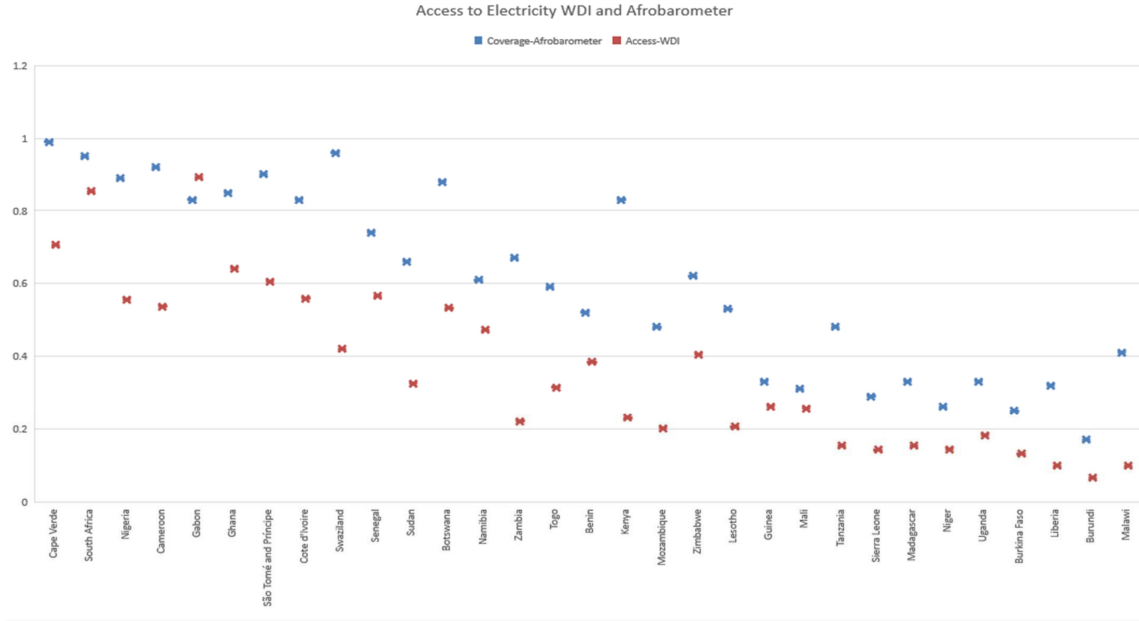


Figure 8: Electrification in Sub-Saharan Africa

To quantify the deficit in access rate (electrification) due to the lack of demand, we employ the methodology developed in the study of coverage of modern infrastructure services in African cities by Wodon et al. (2009). The authors extend a framework used to analyze the infrastructure services in Guatemala (Foster and Araujo, 2004) and improve upon the original accounting-like framework to account for the imperfect measurements of access to electricity. Relying on purely statistical method as in Foster and Araujo (2004) may lead to a substantial bias. Some households may be in covered areas, but they may be too far from the actual grid to be connected. Such household would be mistakenly classified as not connected due to demand factors whereas it is primarily not connected due to lack of supply. Wodon et al. (2009) suggest to use regression to mitigate this type of bias and estimate the take up rates in place of observed take up rates. In our analysis, we diverge from Wodon et al. (2009) as we decompose the demand into different components and therefore we cannot strictly talk about demand-supply decomposition as in Wodon et al. (2009). Below we briefly describe the methodology noting that we focus on the deficit due to the lack of demand. For detailed discussion see Wodon et al. (2009).

Let C denote the share of households using electricity (connected to the grid) divided by the total number of households. Further, let A denote the share of households located in covered areas and U denote the share of households in the covered areas that are using

electricity. Therefore, $A * U = C$. The pure demand side gap can be defined as:

$$PDSG = A * (1 - U)$$

where $(1 - U)$ is the share of unserved households in covered areas. Then the proportion of the deficit in access⁵ that is attributed to the demand side factor can be expressed as $\frac{PDSG}{1-C}$. It is the share of the pure demand gap in the unserved population. To account for the fact that not all households located in the covered areas can connect to the grid due to supply-side factors, we first simulate the take up in covered areas and compute the adjusted pure demand side gap. It is defined as the difference between the simulated access rate ($A * U^*$) and the actual access rate ($A * U$).

$$PDSG = A * (U^* - U)$$

The simulated take up (U^*) is obtained from a regression of households determinants of the take-up. In Wodon et al. (2009) the demand side factors are captured by a single variable denoted as an index of household wealth. We utilize the richness of the Afrobarometer data to estimate the model of the determinants of the take up at a household level and decompose the demand side factors contributing to low coverage into different attributes of income to extend the framework proposed in Wodon et al. (2009).

Using the observed data and estimated coefficients we simulate the take up rate (U^*) conditional on lifting every constraint of interest in isolation. Therefore, we compute the demand side gap and the deficit attributed to the demand side factors separately for each constraint of interest. The proportion of the deficit in access that is attributed to each of the demand side factors can be now expressed as $\frac{(APDSG|demand\ side\ constraint)}{1-C}$. It is the share of the adjusted pure demand gap due to the constraint in question in the unserved population.

4.2 What do households demand electricity for?

Before analyzing the take up of electricity among Sub-Saharan households, let us first consider the current energy use by households across Sub-Saharan Africa. First, given the empirical evidence, it is not surprising to see that households utilize various sources of energy. Energy stacking is a common strategy among African households in which they do not rely solely on one energy source but a portfolio of sources (van der Kroon

⁵In Wodon et al. (2009) it is referred to as deficit in coverage due to differences in definitions.

et al. (2013), Kowsari and Zerriffi (2011)). Our data confirm the fuel stacking theory. Figure 9 summarizes the usage of different cooking and lighting fuels. For example, in Senegal, while 53% of households use electricity as a primary lighting fuel, almost no household uses electricity for cooking. 48% of people who report electricity as a primary source of lighting in the household use firewood as primary cooking fuel, the remaining household use charcoal and gas in equal percentages. The low take up of modern cooking fuels among connected households implies that health hazard related to pollution from burning biomass does not decrease with increased electrification. Moreover, more recent study shows that the increased availability of LED lamps decreases the usage of kerosene in rural Africa substantially. The cost of such lamps can be scaled almost continuously (as it is reflected in the number of LED diodes) and therefore is ideally suited to financially constrained households (Peters and Sievert, 2016). The apparent cost advantages, as well as the widespread access to such source of lightning, significantly decreases the role of grid electrification in providing light to African household.

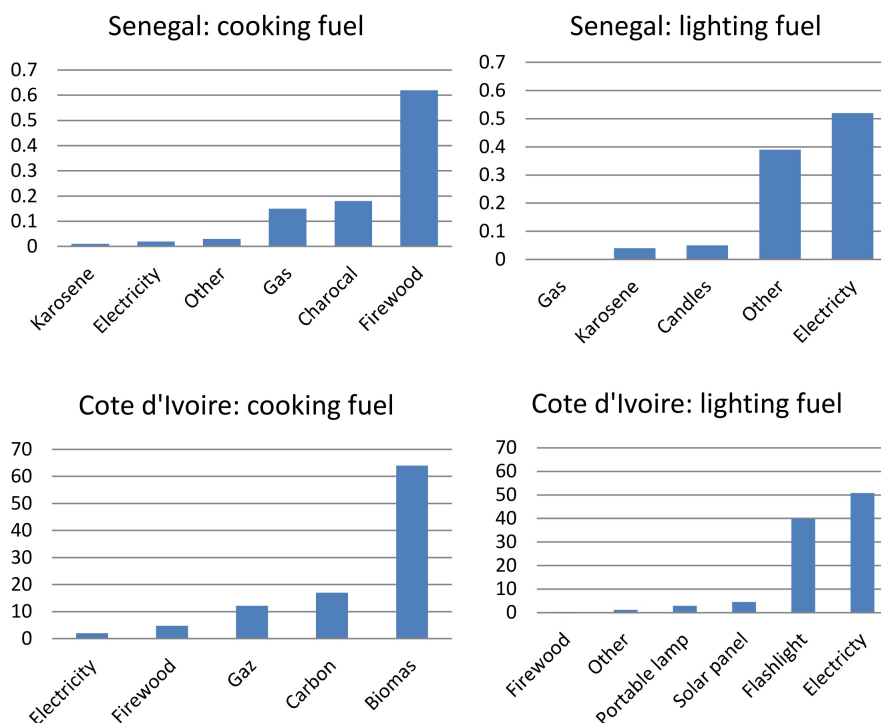


Figure 9: Cooking and lighting fuel in selected countries

Household's possession of appliances is in principle a good indicator of what household demand electricity for. However, the information available in the data is very scarce. Only in few of the countries for which LSMS data are available, have detailed information

on appliance possession can be found. Consider the appliances households report by electricity connection in Senegal presented in figure 10. Not surprisingly households with grid connection are much more likely to have a fridge, a fan, a TV or a modern stove⁶.

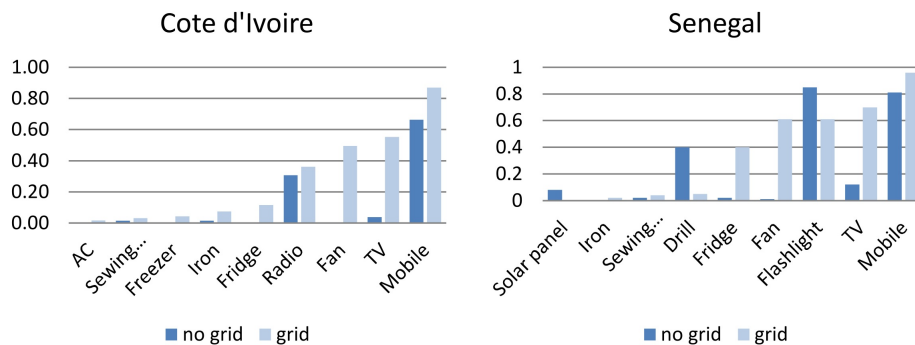


Figure 10: Appliances possession by grid connection in selected countries

Overall, the information available in the data on usage of electricity is very limited. Even if we know whether a household is in possession of particular appliance we cannot say anything about its use. Therefore, we revert to the vast evidence from the qualitative work in Senegal and Nigeria to better understand how household utilizes electricity. Contrary to the common perception that electricity is primarily demanded lighting of the dwelling⁷, our evidence from fieldwork suggests that individuals primarily recognize its productive use. The emphasis is often placed on the desire to bring electricity to a place of work before bringing it to the household. Both in Senegal and in Nigeria households utilize the electricity for productive activities such as the purchase of a fridge to sell cold drinks or purchase of a small electric tool used in welding or carpentry which creates employment opportunities. Even cell phone usage is directly linked to productive activities as it provides principal means of communication.

Also, in rural Senegal, individuals stressed the importance of electricity in agriculture for irrigation purposes. Evidence from India supports the productive use of electricity. Examining the long run effects of the Indian roll-out program Van de Walle et al. (2013) find a substantial increase in labor supply both among men and women. Authors find that men shift leisure time to evening hours and work more regular hours during daytime. Among other, non-financial factors, the desire of an outside light as a status indicator as

⁶The definition of modern stove combines electric and gas stoves.

⁷In Senegal individuals report that the cost of kerosene is incomparably lower than the cost of lighting powered by electricity.

well its importance for safety is often mentioned. Increased public safety through outside lighting is a well-recognized issue in the literature (Kalra et al., 2007).

4.3 Demand supply decomposition

Before analyzing the deficit in access rate in Sub-Saharan Africa and specific countries, we briefly focus on the model specification. The objective of this part of the analysis is to predict connection of households in covered areas which introduces a selection bias to the regression. However, as we are interested in the individual take-up in covered areas, we restrict our sample to areas with grid connection and draw inference on households in covered areas only acknowledging the limitation to extend the results beyond covered areas. Alternatively, a two-stage procedure could be implemented to account for the selection issue. However, such approach is methodologically challenging due to the lack of reliable instrument at an individual level as well as the fact that both the dependent variables in the primary model as well as in the selection equation are binary. Keeping the limitations to generalizing our result, we proceed with probit estimation to decompose the take up gap to supply and demand gap. We do so for the whole region as the country-level samples result in a relatively small number of observations.

To accurately estimate the demand gap, we need first to develop a simple model that will allow us to predict the take up once certain demand-side barriers are removed. The underlying model can be summarized as follows:

$$y_i = I(\mathbf{x}'_i\beta + \epsilon_i > 0) \quad i = 1, \dots, N$$

where y_i is binary variable taking on value 1 if household i is connected to the grid and 0 otherwise and \mathbf{x}_i is a vector of control variables. N denotes the number of households in areas with grid coverage. We select the set of explanatory variables to best capture the critical aspects of the demand side barriers given the information available in the data.

First, we believe that the connection rate in the PSU (primary sampling unit), measured as the share of connected households in the PSU, plays an important role. On the one hand, it is a good proxy for the connection costs. On the other hand, it conveys useful information about potential peer effects. If more households are connected to electricity than benefits (or lack of such) from connection are better visible to other households and might contribute to the overall take up rate. Spillover effects of adopting new technologies in developing countries are well documented. The evidence from the literature

on agriculture in Africa suggests that individuals are more likely to mimic individuals who are similar to them. Given the low take up rates it might be welfare improving to subsidize some households in the community to disseminate knowledge about the benefits of electricity connection. A few fortunate stories can positively affect the individual take up rate and therefore alternative subsidy schemes should be considered. Van de Walle et al. (2013) indeed find some positive spillovers regarding labor supply on unconnected households. The second factor at a PSU level is the economic profile of a locality as it partially captures the productive use of electricity. For example, in opposition to common beliefs, communities involved in agriculture recognize the value of electricity and as the evidence from our field work indicates are often able to carry the connection fees once presented with this opportunity.

With respect to the household level characteristics, an essential factor is the housing quality measured using roof quality in the dwelling. If better housing quality is needed for households to connect to the grid than house improvements programs should precede electrification to achieve high take up rates. Moreover, connecting dwellings that do not pass appropriate standards for human settlement does not appear to be beneficial for the governments. If a significant share of the population resides in informal settlements, then housing improvement program should precede electrification of such areas. For example, in South Africa in the presence of 1.7 million informal settlements, new initiatives were put in place to arrange for people to live in formalized housing before electrification could take place (Niez, 2010).

Finally, we consider the income of a household. On the one hand, we control for household's wealth measured by the wealth index. The wealth of the household captures the possession of appliances as well as the economic situation of the household. It is a well-known fact that financial constraints play a significant role in determining whether a household connects to the grid. Little however is known about the attributes of the households income and its impact on the decision to connect. We try to shed some light on this issue by focusing on the regularity and predictability of income to capture the household's ability to pay monthly. This is measured with the dummy variable indicating whether at least one household member has a full or part-time cash paying job. That is especially important for households in the lowest wealth quintiles.

We also control for household size, gender, age and schooling of the household head

and whether the household is in the urban or rural area.

Finally, notice that an often-overseen issue in related literature is the distinction between individuals in owned and rented dwellings. It is rarely the case that individuals that rent decide whether to connect to the grid and therefore it appears to be reasonable to limit the analysis to owned units only. Unfortunately, this information is not available in Afrobarometer data but it is available for selected countries in the harmonized data, and we will exploit it in further research.

Table 3 presents the results of the probit estimation for all Sub-Saharan Africa as well as for rural and urban areas separately. As expected, rural households face lower connection probabilities. The share of connected households in the PSU increases the probability of connection. The share of professionals positively affects the probability of connection in the whole sample and the urban areas. We also find that the share of individuals in agriculture decreases the probability of connection significantly. At a household level, higher wealth naturally increases the chance of connection. We also confirm the importance of the quality of the dwelling, as measured by the roof quality as well as the importance of regular cash paying income in the rural areas.

Table 3: Probit results

	All	Urban	Rural
% connected in PSU	3.318*** (72.356)	3.592*** (44.760)	3.153*** (54.267)
Urban	0.081** (3.249)		.
Household size	0.040*** (7.960)	0.045*** (5.100)	0.041*** (6.671)
<i>Wealth quintiles</i>			
2	0.323*** (12.028)	0.382*** (8.369)	0.064 (1.582)
3	0.490*** (16.287)	0.647*** (11.465)	0.243*** (6.047)
4	0.720*** (19.461)	0.743*** (10.474)	0.454*** (10.193)
5	0.988*** (23.652)	1.012*** (11.590)	0.771*** (16.320)
High quality roof	0.130*** (4.448)	0.319*** (4.876)	0.120*** (3.610)
Secondary education	0.264*** (9.942)	0.382*** (9.021)	0.203*** (5.790)
Cash paying job	0.077** (2.905)	0.046 (1.091)	0.118*** (3.458)
% in agriculture in PSU	-0.107*** (-3.771)	-0.143* (-2.409)	-0.126*** (-3.849)
% professionals in PSU	0.082* (2.524)	0.109* (2.217)	0.083 (1.884)
Age	0.000 (0.150)	-0.002 (-1.485)	0.001 (1.457)
Female	0.033 (1.581)	0.016 (0.470)	0.032 (1.189)
Constant	-2.399*** (-28.132)	-2.534*** (-20.055)	-2.282*** (-17.739)
<i>N</i>	33479	17600	15879

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Following Wodon et al. (2009) and using the above model specification, we proceed with the estimation of the demand and supply side deficit in access rates. Care must be taken when analyzing these results. As we consider different aspects of the demand side barriers, each of the constraints represents the share of the deficit that is attributed to this constraint and not demand as a whole. Given the data limitation, we consider three constraints: *affordability*, *cash flow* and *housing quality*. The first constraint is measured

with a household wealth index as described above and aims to capture differences in the economic well-being of households. It is well known that poor households are at a disadvantage when it comes to access to electricity and therefore we present it for complexity but we do not emphasize it in our analysis. The next two constraints are of a core importance as they aim to capture a specific attribute of household income and economic situation. While the level of income of a household is undoubtedly important, its predictability and regularity (and often form) are of crucial importance when analyzing access to utilities. Households are required to sign long-term contracts, often face high re-connection fees and/or penalties for disconnecting. A recurring payment of even small amounts can constitute a major problem for households who generate their income on a non-regular basis. Moreover, while the stock of animals or certain durable goods is an indicator of a household wealth, its lack of liquidity makes it less relevant in our context. *Cash flow* constraint aims to capture this aspect of household wealth. Lastly, the dwelling type is also of vital importance. Two households with the same level of overall wealth potentially face very different needs regarding infrastructure. *Housing quality* tries to measure this aspect of household wealth. It is measured with roof quality as this information is available for all countries in the sample. Moreover, it appears to be important in the context of electricity as some types of shelters by law cannot be connected to the grid.

The results are summarized in table 4. The first four columns show the pure demand, pure supply, supply, and mixed gap⁸. The last two columns present the share of the deficit that is attributed to the "demand" and the share of the deficit attributed to other reasons. The share of the deficit that is attributed to the "demand" barriers is equal to the pure demand gap divided by all unserved households. Notice that, there are several factors contributing to the demand side in our analysis. Each time we simulate the demand, we perturb only one factor and leave all other factors at their observed value. Therefore the *demand* gap refers to the share of demand that is driven by the factor that is altered in a simulation.

Consider the statistical approach first. In line with the discussion in the previous section, in urban areas, supply side does not seem to constitute a significant problem. On the contrary, in rural areas, it is the supply side gap that dominates. Sixty-five

⁸The last three measures are only calculated for the statistical approach due to reasons explained above.

percent of the deficit in coverage in rural areas is attributed to supply-side reasons. In contrary, in urban areas, 78% of the deficit in access is attributed to demand-side factors. Nevertheless, even in rural Africa, the demand gap is not negligible as it accounts for 35% of the deficit in access (table 4).

Next turn to the analysis of the three constraints. Our results confirm the fact that the statistical approach is overestimating the take up rate conditional on access. However, it is mostly the case in rural Africa. The estimated demand side gap due to each of the constraint is of similar magnitude for all three constraint. However, as demonstrated in the last two columns of table 4 even small changes in the size of the demand gap result in substantial changes in the share of the access deficit. In urban areas, 53% of the deficit is due to broadly understood affordability constraint. Thirty-five percent of the deficit can be attributed to low housing quality or lack of permanent cash paying jobs. About 98% of households affected by roof quality constraint is also affected by the cash flow constraint and about a half of households that respond to the affordability constraint also respond to one of the two remaining constraints indicating that often quite specific needs of the households must be addressed to increase take up rates. The fact that the same households respond to the cash flow and roof quality constraints explain the equal shares of the coverage gap induced by both constraints.

Table 4: Demand supply decomposition for Sub Saharan Africa. Comparison of different constraints

	PDSG	SSG	PSSG	MDSG	% deficit "demand"	% deficit rest
<i>Statistical approach</i>						
All Africa	0.19	0.27	0.20	0.07	0.41	0.59
Urban Africa	0.13	0.04	0.03	0.00	0.78	0.22
Rural	0.23	0.43	0.26	0.17	0.35	0.65
<i>Wealth quintile</i>						
All Africa	0.09				0.22	0.78
Urban Africa	0.11				0.53	0.47
Rural	0.09				0.14	0.86
<i>Cash paying job</i>						
All Africa	0.07				0.12	0.88
Urban Africa	0.09				0.35	0.65
Rural	0.05				0.08	0.92
<i>Roof quality</i>						
All Africa	0.07				0.12	0.88
Urban Africa	0.09				0.35	0.65
Rural	0.04				0.08	0.92

4.4 Rethinking the cost of electricity to households

To understand the demand for electricity, we must first correctly assess the costs of a grid connection to households. Such costs naturally include the connection cost, and the tariffs household pay for usage of electricity. It appears to be prevalent in the literature to limit the definition of cost to the above components. Cost is simulated based on the local connection fee and tariffs per unit of electricity consumed. However, it appears that an accurate assessment of the cost of connection requires a much more detailed approach. First, very often the households are not equipped with meters in which case their monthly bill is based on some averaging of the local usage. In Nigeria, people talk about *crazy bills* reflecting the fact that monthly amount does not reflect the actual consumption and is constant regardless of the actual usage which often is determined by the frequent blackouts. Second, to request the connection a household must often travel to the nearest location of the distribution company which can often absorb significant financial and time resources. The data shows that areas with paved roads which significantly lower the cost related to obtaining the service are much more likely to be covered by the grid and enjoy higher take up rates. More than twice as many households are connected in areas with access to paved roads, with only 20% of households connected in areas without paved roads and 47% reporting grid connection in areas easily accessible. Similarly, conditional on the area being covered by the grid, only 11% of households in areas without access to public transports are connected to the grid versus 39% of households in areas with such access.

Lastly, given that the empirical evidence suggests that lighting is not the primary reason why households demand electricity, the cost of appliances should be taken into account. For a credit constrained household cost of a fridge, a drill or a TV is a significant expense and needs to be factored in the fixed cost of acquiring the connection to the grid. The question of assessing the cost is directly related to the issue of assessing affordability. First of all, a distinction needs to be made between affordability and willingness to pay. If the cost of electricity is high and requires a household to redistribute the expenditure away from other desired purposes, such as children schooling, it is no longer evident if electricity connection is socially desired for this household. Second, up to our knowledge, no study recognizes the productive use of electricity, which appears to be the most important reason why people desire electricity. Individuals recognize the home production possibilities

electricity provides them with. The revenues generated because of the connection need to be measured to understand the affordability constraint better.

4.5 Rethinking access

A binary indicator of household connection does inform us well on the issue of grid coverage and willingness of people to connect to it but can be very misleading when we try to understand access to modern energy or analyze the impact of electricity on individual lives. Since reliability remains a significant problem in many Sub-Saharan countries, it cannot be ignored when assessing the access to electricity.

To illustrate the scope of the problem, let us define access to modern electricity as access to electricity at least most of the time. Figure 11 presents the percentage of households in Sub-Saharan countries which have access to modern energy as defined above. It is striking to see that some countries, such as Nigeria, now appear as having low coverage rates, even though it previously appeared to have a close to 100% coverage rate. Such discrepancies illuminate the importance of defining modern access to energy to understand the energy poverty problem across Sub-Saharan Africa. MTF project⁹(Bhatia and Angelou, 2015) is an excellent attempt to change the way we think about energy poverty and aims to generate new data to help us better understand this issue. Only in South Africa three in every four households is connected to reliable electricity (the household has electricity most of the time or always). In contrast, in Burundi and Guinea, only 4% of households are connected to reliable electricity. On average, only 33 percent of households in Sub Saharan Africa are in areas covered by reliable electricity. Rural Africa remains at a disadvantaged position with only 18 percent of households in covered areas. In urban areas, the situation is better but still less than 1 in every two households is in areas covered by reliable electricity. These statistics highlight the fact that the problem of electrification of Africa is merely limited to the expansion of the grid.

⁹Multi-tier framework

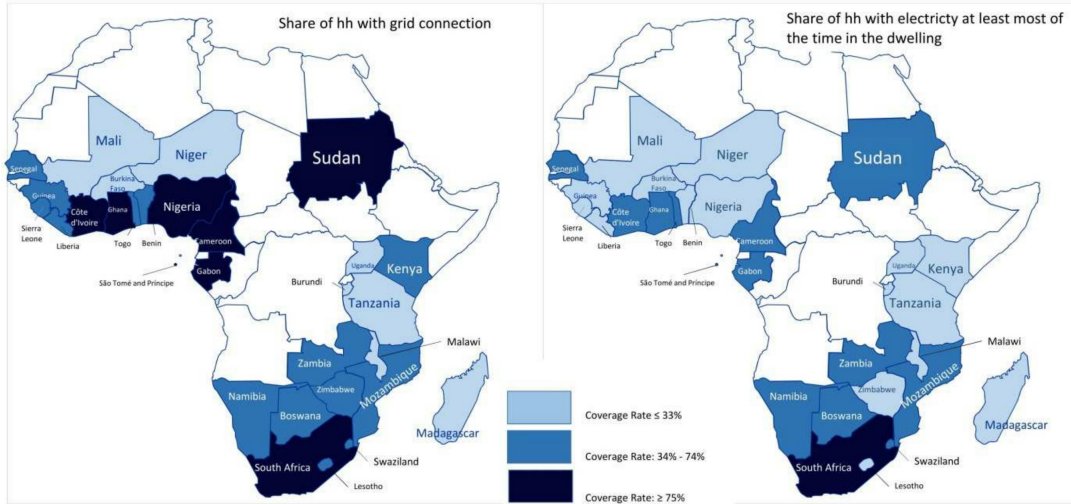


Figure 11: Access to modern electricity

Table 5 reveals that it is indeed the case that households in areas with more reliable electricity are more likely to connect to the grid than when we considered an unrestricted definition of access to electricity. Notice moreover that once we condition on the reliability of electricity the take up rates in rural areas is relatively high. This fact highlights the need for appropriate infrastructure development to guarantee reliable electricity in electrified areas and ensures high take up rates.

Table 5: Take up rates and access to reliable electricity

	Access to any electricity	Access to reliable electricity
All Africa	0.74	0.82
Urban Africa	0.88	0.88
Rural	0.59	0.72

As we restrict the sample to areas with reliable electricity the size of the supply gap increases across the board per the statistical approach as illustrated in table 6. It is especially the case in urban areas where the pure supply side gap increased from 0.03 to 0.27 and the corresponding deficit in access due to supply side increased from 22 to 76 percent. These results suggest that accounting for reliability of available electricity is crucial to correctly quantify the demand and supply side deficit. It also points to the fact that reliability remains a widespread issue that concerns both rural and urban areas. Furthermore, it highlights the need for a measure of access to electricity that captures different aspects of the service provided. Among other features that can affect the demand for electricity is its safety, predictability and capacity.

Table 6: Access to modern electricity: demand-supply decomposition for Sub Saharan Africa

	PDSG	SSG	PSSG	MDSG	% deficit "demand"	% deficit rest
<i>Statistical approach</i>						
All Africa	0.09	0.43	0.35	0.08	0.17	0.83
Urban Africa	0.10	0.32	0.27	0.05	0.24	0.76
Rural	0.12	0.47	0.37	0.10	0.20	0.80

Our analysis confirms the presence of non-trivial demand-side barriers to electricity access among households in Sub-Saharan Africa. Our results suggest that electrification efforts must account for the profile of households in targeted areas and possibly consider various programs that may be improving the economic situation of households before electrification.

5 Community level take up rate

So far, we have focused on a household and its propensity to connect to the grid. We now shift the focus of analysis to the second channel through which electrification rate can increase. We turn to the analysis of a take up rate at a community level. Development efforts often target communities and not individual households thus analysis at a locality level is of core importance from a policy perspective. We define a community at a PSU level. Even though policymakers do not target PSU's but well defined administrative units, using a higher level of aggregation would introduce much noise in the measure of access at a community level for each household.¹⁰

Since areas covered by the grid are not randomly selected, we employ Heckman two-stage estimation procedure (Heckman, 1976) to address the selection bias. In that way, we can extend our results to not covered areas and analyze the predicted take up rates. In our empirical investigation, we employ the 2014 Afrobarometer data. We pool data from all Sub-Saharan countries and aggregate all variables at a PSU level. Table 7 presents the comparison between covered and uncovered areas. For the sake of brevity, we only include the characteristic along which substantial differences are observed. Fewer individuals in covered areas are employed in agriculture and trading and more hold professional jobs. The covered communities are more likely to have access to piped water, sewage infrastructure, paved roads and public transport. Banks, markets, post offices, and clinics

¹⁰There were four PSUs in our data that span over more than one administrative level. These PSUs are omitted in our analysis.

Table 7: Comparisons of areas under and off grid

	Under the grid	Off grid
% in agriculture	0.04	0.23
% in trading	0.04	0.13
% upper professional	0.11	0.09
Pipped water	0.68	0.28
Sewage	0.38	0.01
Bank	0.31	0.07
Market	0.69	0.54
Public transport	0.88	0.64
Post office	0.26	0.46
Clinic	0.6	0.46
Paved roads	0.6	0.28
% with secondary schooling	0.38	0.1
% with cash paying job	0.3	0.17
% with high quality roof	0.85	0.53
GDP per capita	4.92	1.73
Polity index	4.74	3.82
% of president ethnicity	0.25	0.41
Ethno linguistic fragmentation	0.73	0.62
Mo Ibrahim infrastructure score	41.42	32.25
% thinking electricity is imp issue for gov	0.17	0.14
% thinking gov is handling electricity well	0.62	0.49
% with reliable electricity	0.56	-

are more likely to be present in communities under the grid. The share of individuals with secondary schooling or cash paying jobs is higher in the localities covered by the grid, and high-quality roofs are twice as much likely in such localities. These crude summary statistics suggest that areas enjoying a higher level of infrastructure and economic development are also more likely to have access to the grid.

Interestingly, the share of individuals who think that electricity is an essential issue for the government is higher in the communities that are covered by the grid. At the same time, the share of individuals who thinks that the government is handling the issue of electricity well is higher among communities without access to electricity. That may be a result of the massive problem of reliability which is more visible for individuals in communities under the grid. As evident from Table 7, only in 56% of the communities covered by the grid at least one household reports having at least most of the time.

Communities under and off grid vary significantly in terms of observable characteristics as documented above and they are also very likely to differ in terms of unobservable characteristics, we proceed with a selection model. The model can be summarized as

follows:

$$\begin{aligned} \text{Take up rate}_c &= I(\beta x_c + v_c > 0) * \text{Access}_c \\ \text{Access}_c &= I(\gamma z_c + u_c) \end{aligned}$$

where c denotes a community ($c = 1, \dots, C$). X is a vector of community characteristics that can be broadly categorized in three groups. The first group comprises indicators of available infrastructure such as access to piped water, sewage, cell phone reception and paved roads, as well as the presence of a school, a bank, a market, a clinic and a post office. This category also includes the average connection rate as well as the share of individuals with access to reliable electricity which we define as having electricity at least most of the time. The second category contains variables describing the socioeconomic status of individuals and households in respective communities such as the fraction of individuals with secondary education or cash-paying jobs, unemployment rate and share of households with high-quality roofs as well as a set of variables capturing the type of activities in which members of society are involved. The latter include agriculture, trading, unskilled work, skilled work, clerics, supervisors, security, top professionals and others. The last set of variables composes of economic indicators at a country level such as GDP per capita, population density, share of the population of the same ethnicity as the president, polity score, ethnolinguistic fragmentation, Mo Ibrahim infrastructure and business rural sector scores. The Heckman selection model is theoretically identified even when the set of variables in X and Z is the same. Nevertheless, to ensure that the model is well-identified, we include three exclusion restrictions. Therefore, in the selection equation, vector Z contains all variables that are in X and additional variables (exclusion restrictions). The first instrument we employ, *contact with government agency*, aims to capture the community connection to the government. It is a dummy variable that takes value one if at least one individual in a PSU reported contacting a member of a government agency at least once within the last year. As revealed during the field-work, a significant amount of bureaucracy is often involved in bringing electricity to a community and having a representative in a government willing to assist a community in obtaining coverage might be an essential asset. Therefore, often contact with members of government agencies can directly influence the probability of grid connection at a community level. It is possible however that it also affects other economic activities in the region which can affect the take up rates. Nevertheless, controlling for such activi-

ties in the main equation should reduce this confounding effect. The second instrument concerns the primary source of electricity. Given the fact that hydro and gas are the two primary sources of electricity in the countries considered in the analysis, we attempted to include two dummy variables indicating which of the two accounts for most electricity produced in a country. Due to a high correlation between the two indicators, we only include the indicator for hydro being the main source of energy. The rationale behind this instrument relies on the fact that source of energy determines the costs of both generation and distribution. Therefore, it affects the grid expansion but should not have a direct effect on the community level take up rate. Because such costs can be reflected in the prices, we run a series of regression to see if the primary source of generation is reflected in the prices at different levels of electricity consumption. We find that there are no significant differences between hydro and gas regarding electricity prices¹¹. We also conduct robustness check where we include country-level tariffs to minimize the potential confounding effect. The last instrument we employ is the lagged population density at a country level¹². We present results including population density in 1990, note, however that, the results are not sensitive to the choice of the year for which we record the past population density. More densely populated countries face lower costs of electrification, and therefore it directly affects connection rates. However, since we control for contemporaneous population density at a country level, the historical density should not directly affect the contemporaneous connection rates¹³.

There is a total of 6055 communities in our sample, 3782 of which are currently covered by the grid. However, since lagged population density is not available for all countries, we lose about 10 percent of the sample. In urban areas, 94% of the communities are covered by the grid implying that selection does not present itself as a significant issue. On the contrary, in rural areas, less than 50% of communities are currently covered by the grid. Since the variation in coverage is minimal in urban areas, in addition to the estimation for as Sub-Saharan Africa, we estimate the model for rural areas only. While it is certainly important to understand what are the characteristics of the 6% of the urban communities that do not have access to the grid, we believe that qualitative work is better equipped to do it. Since the list of co-variates included is long, for the sake of brevity in all tables

¹¹However, note that the sample is small (31 countries).

¹²We do not have detailed information about the population density at a finer administrative level

¹³Other instruments considered for future investigation include distance to generation facility and distance to capital city.

with results we select the variables with significance.

The results of the first step summarized in table 8 are of importance to policymakers as they help determine what type of communities are more likely to be connected to the grid. Most importantly for our identification strategy, the three instruments we employ, the dummy variable indicating whether hydro is the primary source of energy, lagged population density and contact with a government agency, all appear to predict coverage in the area well, both in the whole sample and rural areas. Consistently with previous evidence, rural areas are at a massive disadvantage regarding grid coverage. Similarly, areas with better infrastructures are more likely to have access to the grid. Communities with wealthier households with better quality roofing are also more likely to be covered by the grid. Overall, it appears that grid coverage comes together with other development efforts and communities which already enjoy and benefit from better infrastructure are more likely to be covered by the grid. Note that our analysis excludes the cost of bringing electricity to an area, which can bias the results for other characteristics. If such cost is negatively correlated with the infrastructure indicators which is likely to be true, then the differential along the infrastructure indicators may just reflect the differences in costs and not the causal effect of infrastructure on the probability that an area is connected. We acknowledge this is a limitation of our study which limits the scope of conclusions we can draw from the first stage of our analysis. Unfortunately, due to data limitation, we cannot address the issue of costs of electrification directly.

We interpret the results mainly as correlations, although we add as much control variables as possible to deal further with the selection issues. We proceed with the analysis of marginal effects to better understand the context in which characteristics correlate with the grid connection of the locality. We focus on rural areas. We explore different scenarios of infrastructure development at a community level to establish what level of infrastructure development allow communities to benefit the most from other factors regarding grid connection. We divide communities into three categories. The first category (*Basic*) comprises localities with only necessary infrastructure, which we consider to be a school and a clinic. The second group (*Average*) contains communities with basic infrastructure and a market, a post office, access to public transport, cell phone reception and access to water and paved roads. The third group (*All*) comprises of communities endowed with all the above and a bank and sewage system. We consider

Table 8: Determinants of access to the grid: first stage results

<i>Grid coverage</i>		
Rural	-0.535***	
	(-7.394)	
% thinks electricity is handled well	0.824***	0.777***
	(7.801)	(6.741)
Hydro as main energy source	0.510***	0.488***
	(6.894)	(5.903)
Lagged population	0.038***	0.028**
	(4.345)	(2.864)
Contact with government agency	0.112**	0.114**
	(2.939)	(2.853)
% in agriculture	-0.193*	-0.250**
	(-2.209)	(-2.711)
% in trading	-0.212*	-0.255*
	(-2.199)	(-2.498)
Access to water	0.300***	0.223***
	(4.954)	(3.354)
Access to sewage	1.027***	1.068***
	(7.889)	(6.144)
Bank	0.319***	0.153
	(3.413)	(1.413)
Public transport	0.178**	0.170*
	(2.695)	(2.392)
Post office	0.469***	0.529***
	(4.587)	(4.557)
% with secondary schooling	1.018***	0.953***
	(6.232)	(4.989)
% with cash paying jobs	0.357***	0.223
	(3.378)	(1.939)
% with high quality roof	0.374***	0.408***
	(4.117)	(4.211)
Av. wealth index	1.010***	1.038**
	(3.373)	(3.173)
% of population of president's ethnicity	-1.547***	-1.503***
	(-15.175)	(-13.411)
Mo Ibrahim infrastructure score	-0.035***	-0.037***
	(-9.233)	(-8.597)
Constant	0.200	-0.131
	(0.750)	(-0.457)
<i>N</i>	5340	3315

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

changes in three community-level characteristics that capture the economic livelihood of the locality: share of households with a high-quality roof, the share of households with cash paying jobs and the average wealth of households. Figure 12 summarizes the results showing that the least developed communities benefit the most from a higher fraction of individuals with cash-paying jobs, a higher fraction of individuals with high-quality roof and increase in average wealth. If governments tend to bundle development programs, then extra effort is required in the less developed communities to obtain grid coverage, and that is manifested by the larger marginal effects for all three factors.

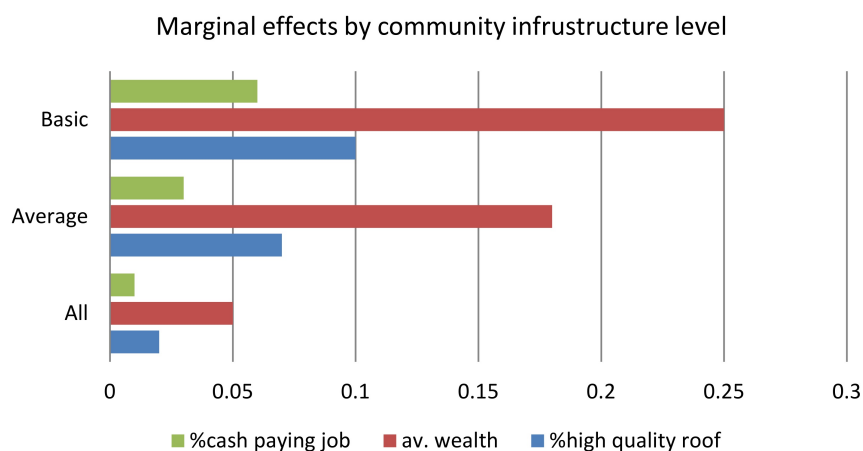


Figure 12: Marginal effects of selected variables by community infrastructure development

Next, consider the results of the main equation summarized in table 9. The first three columns present the results of OLS estimation for all, urban and rural areas separately. The last two columns summarize the results of the Heckman selection model for the whole sample and rural areas. The comparison between OLS and Heckman results reveals substantial selection bias for some covariates manifested in considerable differences between the magnitudes of the estimated effects. We focus on the last two columns. All infrastructure indicators, as well as variables capturing households' well-being positively, affects community-level take up rates. This delivers further evidence that economic well-being of a community is crucial for a community to enjoy a high take up rate. Hence it must either precede the presence of grid coverage or otherwise; electricity must enable individuals to raise their economic well-being.

Among country-level indicators, notice that the take up rate decreases with the share of the population that is of president's ethnicity. If this variable is a good proxy for

political competition, such negative correlation is consistent with the politician efforts along development goals deemed necessary to win elections. The larger the political competition, the more resources may be devoted to the maintenance of the infrastructure and thus more reliable electricity is available which can very well increase the take up rates. We do not have the necessary information to confirm such conjectures in the data. However, our results do confirm that take up rates increase with a higher share of households enjoying electricity at least most of the time. Also, the evidence from our fieldwork suggests that frequent blackouts experienced in the community can deter unconnected households from connecting.

For electrification efforts to be successful the take up of electricity in targeted communities need to be high. Our results show that more effective targeting strategies can be developed to ensure higher take up rate in the community. That is manifested in the negative correlation between the unobservable characteristics in our estimation (ρ). That result suggests that the selection of communities for grid expansions does not fully utilize the underlying potential and more strategic targeting could result in higher take up rates. The average truncation effect in the sample of communities with access to the grid in the rural areas is -0.49 (*av.inverse mills ratio* $\times (-0.176)$) indicating that the take up rate in an average rural community is 4.7 percent ($[\exp(\text{av.truncation}) - 1] \times 100$) lower than it would be in a randomly selected rural community.

To shed some more light on the selection process, consider the summary statistics of the rural communities with high and low truncation effect presented in table 10. Smaller truncation effect in absolute terms is associated with a smaller decrease in the take up rate in the community of given characteristics relative to a randomly selected community. For the sake of brevity, we only include the characteristics that showed substantial differences between the two groups. The differences among all the characteristics confirm the main result of this analysis showing that economic livelihood and development of a community diminishes the adverse selection effect.

Table 9: Determinants of take up rates: OLS and Heckman selection model results

<i>Take up rate</i>	OLS			Heckman	
	All	Rural	Urban	All	Rural
Rural	-0.068*** (-7.473)	.	.	-0.065*** (-7.555)	
% with reliable electricity	0.099*** (6.426)	0.127*** (6.384)	0.062** (2.688)	0.096*** (7.909)	0.122*** (7.109)
% in agriculture	-0.054** (-2.751)	-0.002 (-0.108)	-0.185*** (-3.429)	-0.029 (-1.563)	0.014 (0.637)
% in clerical occupations	0.066*** (3.823)	0.116*** (4.004)	0.008 (0.448)	0.063*** (3.311)	0.112*** (3.543)
Access to water	0.121*** (11.009)	0.110*** (8.465)	0.146*** (7.747)	0.109*** (11.433)	0.102*** (7.937)
Sewage	0.088*** (9.952)	0.144*** (9.644)	0.058*** (5.409)	0.073*** (7.732)	0.123*** (7.147)
Bank	0.026* (2.541)	0.024 (1.365)	0.022 (1.931)	0.028** (2.695)	0.028 (1.583)
Market	0.029** (3.058)	0.045** (3.190)	-0.000 (-0.032)	0.028** (3.089)	0.049*** (3.565)
School	0.011 (0.983)	0.032* (1.983)	-0.014 (-1.110)	0.023* (1.989)	0.046** (2.704)
Access to paved roads	-0.047*** (-5.581)	-0.034** (-2.635)	-0.019 (-1.804)	-0.048*** (-5.794)	-0.036** (-2.854)
% with secondary schooling	0.138*** (9.182)	0.169*** (6.703)	0.082*** (4.647)	0.111*** (6.990)	0.132*** (5.003)
% cash paying job	0.061*** (3.727)	0.059* (2.465)	0.061** (2.964)	0.048** (3.016)	0.049* (2.106)
% with high quality roof	0.185*** (10.023)	0.119*** (5.870)	0.266*** (6.070)	0.145*** (8.414)	0.084*** (3.837)
Av. wealth index	0.142*** (3.729)	0.209*** (3.554)	0.063 (1.484)	0.138*** (3.503)	0.193** (3.226)
% of president's ethnicity	-0.173*** (-9.629)	-0.237*** (-8.780)	-0.173*** (-7.178)	-0.122*** (-7.231)	-0.162*** (-5.944)
Constant	0.347*** (10.264)	0.356*** (6.456)	0.387*** (7.071)	0.427*** (12.140)	0.423*** (7.924)
Mills lambda				-0.102*** (-12.750)	-0.097*** (-6.031)
ρ				-.480 *** (-12.632)	-0.422*** (-6.763)
<i>N</i>	3921	1940	1981	5340	3315

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 10: Summary statistics by truncation effect

Truncation in absolute terms	Low	High
%in agriculture	0.02	0.13
%in trade	0.01	0.11
Pipped water in community	0.62	0.31
Sewage in community	0.28	0.01
Access to cellular network	0.91	0.81
Bank in community	0.26	0.12
Market in community	0.70	0.57
Public transportation	0.86	0.79
Post office in community	0.26	0.1
Access to paved roads	0.52	0.40
% with secondary schooling	0.40	0.15
% with jobs with cash	0.28	0.22
% with high quality roof	0.86	0.62
GDP per capita (in thousands USD)	5.64	1.76
Mo Ibrahim infrastructure score	42.81	32.37

6 Conclusions

Despite the rich literature on electrification of Africa, not much is still known about the demand for electricity at a household level. This paper aims to examine the demand side barriers that household face when deciding whether to connect to the grid. The share of households located in areas with no access to the grid is still large, and governments must undertake appropriate actions to bring electricity to these areas. However, our results highlight the need for implementing programs and policies that will help households in already electrified areas connect to the grid. One time subsidies and low connection fees might not be sufficient considering lack cash paying jobs that ensure affordability of connection. Struggling to pay monthly bills and high disconnection fees may result in a redistribution of households income away from other desirable causes such as education and healthcare. Inability to purchase desired appliances for credit-constrained households might also serve as a deterrent. The low-quality housing may deter electricity companies to offer connection and deter households from connecting in the presence of more pressing needs.

Furthermore, our findings show that governments can achieve higher coverage if they better target the electrification efforts. High take-up rates are necessary for successful electrification. Economic livelihood of a community is crucial for generating high take up

rates. Therefore, governments should target communities which already enjoy economic well-being or provide electricity in communities in which the economic well-being is likely to be induced by the presence of electricity.

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