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Access to electricity in Sub-Saharan Africa:

the regressive effect of tariff structures on urban and rural on-grid households

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Abstract

In sub-Saharan Africa (SSA), the energy access gap between urban and rural populations remains considerable, even among households and businesses with potential access to the grid. As the interface between electricity generation conditions, the end user and public energy-access policy, tariff structures are the major instrument of access. This article evaluates how electricity tariff structures contribute to the continued existence of the energy access gap and looks at whether this gap is primarily between rural and urban populations. Using a dynamic panel model with random effects (1990-2012; 33 countries divided into 4 groups; 17 variables related to residential and non-residential consumption, production and share of income spent on electricity), the article shows the systematically regressive effect of electricity pricing on access to both residential and non-residential consumption. We find that electricity pricing fails to provide reduced rates that enable access to the poor, neglects households that have passed the threshold of the first consumption block and is ineffective at addressing energy poverty in both urban and rural households. For households to access a centralised power grid, we find that the criterion of location is less important than the economic conditions of the customers served.

Keywords: Power tariff structures, Electricity access, Urban on-grid access, Rural on-grid access, Rural electrification

JEL Classification: Q48, I38, N17, O11

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1. Introduction[3][4][5]

All developing countries are making strides to universal access to electricity except those in sub-Saharan Africa (SSA), where the electrification rate has barely reached 45% (IEA, 2019). Even so, SSA has made undeniable progress in electricity access (IEA, 2019). These gains have occurred within at least three structural constraints (Hafner et al., 2018). First, the population of SSA is predicted to double by the year 2040. Moreover, this progress in access is occurring in a context of great spatial heterogeneity: the rural access rate has reached only 23% as opposed to 71% in urban areas (IEA, 2019). At the same time, most of the growing African population is likely to be concentrated in rural areas until at least 2040 (UN, 2019). Finally, these gains in access need to be seen in terms of the economic growth dynamics that they are likely to cause (IEA, 2019).

With the adoption of the SDG7, the definition of access has been enriched (Bathia & Angelou, 2015), measuring affordability, reliability and sustainability. Now that access is increasing, studies are focused more on its effects (Riva et al., 2018) and the means employed to achieve it. The electricity grid is the dominant means of access (SEforALL, 2020). Grid access can be defined by three elements (Banerjee et al., 2008). The first is people living near the power grid, and the second is the number of people connected to the grid. The third element is coverage: the percentage of people who could have access to the electricity infrastructure but who refuse it, mostly for financial reasons. In this article, we are looking at study access in terms of the coverage rate.

The gap between urban and rural access rates calls attention to the different methods of enabling rural electrification (Peters & Sievert, 2015). In developing countries, the means of financing rural electrification through the allocation of cross-subsidies between rural and urban populations is insufficient because of major distortions related to capital costs, higher operating costs than in urban electrification and scattered settlements (Hourcade et al., 1990). Moreover, the growth in the value of

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electricity produced for cities (Huenteler et al., 2017) to create a surplus (Dinkelman 2011) is uncertain given the many failures of on-grid power, the already large subsidies from those with service and the inability to increase access without public financing, given the poverty of those without service (Perez-Ariaga et al., 2019). In this context, decentralized solutions contribute most to rural electrification (Mahapatra & Dasappa, 2012; Levin & Thomas, 2016; Peters et al., 2019). However, for the areas that currently have on-grid service or are targeted for grid expansion, the question is how the establishment of tariff policies can guarantee access to electricity and increase consumption for a critical mass of customers (Ntagungira, 2015), given that 40% of future access has been estimated to be on-grid (IEA, 2019).

Over the past decade, interest in the power tariffs in SSA has been growing. The literature has analysed the effect of pricing on household and productive access in three ways, generally addressed separately. Studies of supply emphasise the power system's forms of organisation (Eberhard et al., 2011; 2017). Studies on demand identify different types of consumers - residential, productive - and focus on the question of consumer targeting (Komives et al., 2005; Briceño-Garmendia & Shkaratan, 2011; Kojima et al., 2016). Finally, studies of willingness to pay describe the behaviour of the poorest households, generally in rural areas, to determine the best means of electricity access (Sievert & Steinbucks, 2020).

All these factors in the literature point to a broader question: is pricing a major instrument of access? In this way, it is first necessary to consider that tariff structures serve as the interface between the end user and the overall conditions for producing electricity while reflecting public energy-access policies. Secondly, given that a significant share of access is - and will continue to be - grid-based, and that urban access is now growing somewhat slowly while rural access is not growing at all, it is necessary to assess how much tariff structures contribute to upholding the electricity access gap between urban and rural consumers in SSA.

Using data gathered from the regulatory commissions of 33[i] SSA countries, we analyse electricity access to urban and rural households connected to the grid through a dynamic panel data model with random effects (Hsiao, 2003) for the period of 1990-2012. We use independent variables tracking the key dimensions of access: the tariff structures within the context of the type of electricity production and the share of income in electricity. This latter dimension expresses consumption potential, whereas tariffs designate only attainment. Our empirical work is based on a country typology by energy poverty and access rate.

Our research question will be explored as follows. Drawing on a literature review on tariffs, section 2 identifies the critical points in their implementation. Their regressive nature makes it possible to identify elements to be addressed in our empirical strategy. Section 3 describes the data and specifies the model. The main and robustness results are discussed in Section 4. The study of the determinants of on-grid electricity for rural and urban households highlights the limitations of existing tariff structures in both reducing energy poverty and strengthening the consumption of those with on-grid electricity access. In the end, the question of access appears to be more an economic issue than a question of population location. Section 5 concludes the discussion and introduces some policy implications.

2. Literature review on tariffs

We use the available literature to identify the critical points of the tariffs implemented in SSA, keeping the distinction between tariffs for residential and productive use. In SSA, the implementation of residential tariffs fails to differentiate among consumers. This weakness in targeting is explained by tensions between the objectives of meeting consumer needs and recovering costs in the context of extreme poverty. Furthermore, specific instruments to address fuel poverty, such as lifeline rates and consumption subsidies, have failed to reach their target. Residential tariffs are therefore regressive. In the case of production tariffs, subsidisation is also massive. Both types of tariffs thus struggle to achieve their targets for promoting access.

2.1 Residential sector: The adverse effects of progressive pricing on electricity access

Among the three possible forms of pricing for households (Hansen & Percebois, 2019), progressive pricing is used by about 55% of the countries in the world and even more in developing countries (Ntagungira, 2015). One-third of SSA countries use single tariffs, while two-thirds of them use progressive tariffs (Briceño-Garmendia & Shkaratan, 2011).

In SSA, as everywhere else, progressive pricing is used because it allows providers to segment consumers by consumption blocks. When the price per kWh increases with each consumption block, the progressive pricing is an Increasing Block Tariff (IBT)[ii]. This makes it possible to combine a low price to ensure basic consumption with a price that increases with consumption. This pricing also allows power production facilities to recover costs from the last bracket. Consumer targeting is thus decisive in simultaneously ensuring equity and efficiency objectives.

2.1.1. Progressive pricing offers little differentiation between consumers

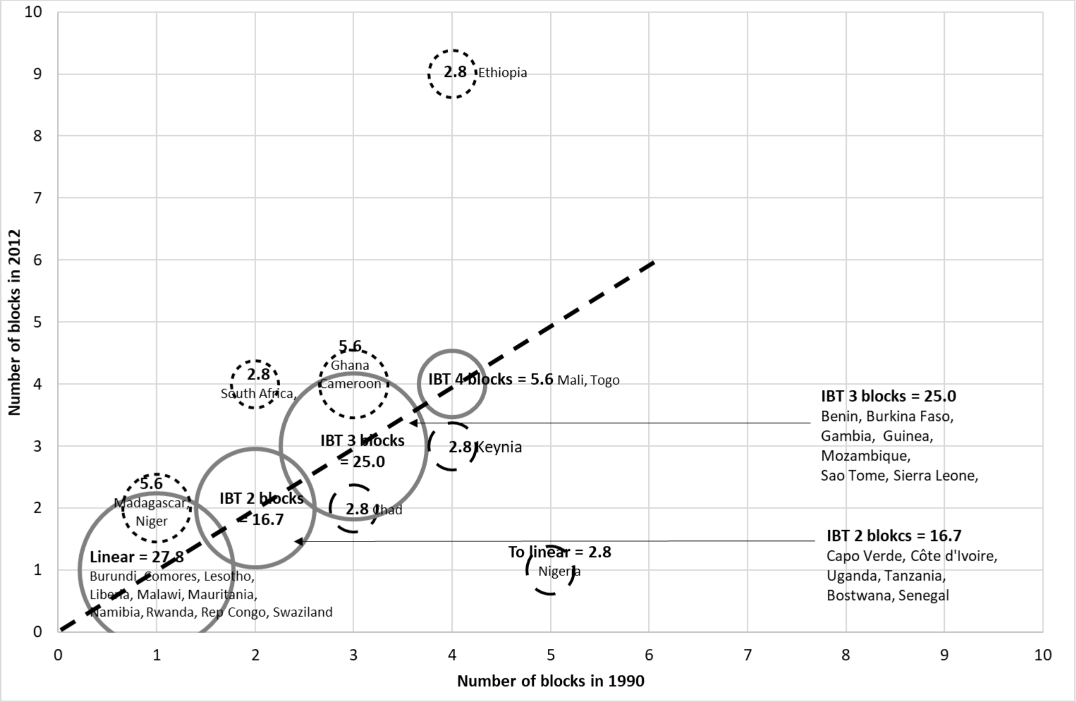
In SSA, the implementation of progressive pricing is difficult because the consumption of high-income industrial or residential consumers is not enough to offset the mass of low-income consumers who receive subsidised pricing. Consequently, consumer segmentation in SSA faces a dilemma: the predominant progressive pricing structures have an adverse effect on the electricity access that they claim to promote while not allowing electricity companies to cover their costs.

The effectiveness of progressive pricing assumes prior knowledge of price elasticity of demand for electricity by use and by customer. However, in SSA, where these elasticities are unknown, tariff design must often respond to competing objectives. If the established tariff design does not allow real tariff segmentation between consumers and the tariffs are not high enough to completely cover production costs, the overall power infrastructure is not viable over the long term. However, if the public utility sets the price of electricity as the real cost of production, many households risk being cut off from power services. Overall, the blocks corresponding to high usage rates are supposed to be paid by higher-income households, based on a positive relationship between energy consumption level and income.

Generally, even though these rates ($0.02-0.36 per kWh) are high enough to be inaccessible to a large portion of the African population[iii], they are insufficient for public power companies to recover production and operating costs[iv] (Eberhard & al., 2008; AfDB, 2013). There is as of yet no way to simultaneously solve the problems of cost recovery and affordability.

Given these factors, the first criticism of progressive pricing involves its limited ability to create price discrimination between the rates paid by different households. In SSA, public utilities tend to favour the use of several consumption blocks, but the price differences between the different consumption blocks are small. In ten countries, in fact, there is no price difference between the first and second consumption blocks (Eberhard et al,. 2017).

Therefore, in SSA, most of the progressive pricing structures continue to be extremely simple: two or three consumption blocks. Countries have rarely chosen large increases in rates. Moreover, the tariff structures appear to be very stable over time, since in 75 % of cases, the structures in 2012 are identical to those in 1990.



Authors - Data from national energy regulators

Figure 1. Comparison of tariff structures in 1990 and 2012 (%) for the SSA countries.

Another element highlighted in the literature is connection fees. Consumers must reimburse the power company for their total capital cost over a period of up to 30 years. Some countries completely subsidise this cost. However, more than half of SSA power companies charge a flat fee to cover grid costs. This fee often entails a substantial expense for households. Per month, these fees can be low, from \$0.80 to \$1.66 when they are partially subsidised, but in extreme cases, they can be over \$17 (Golumbeanu & Barnes, 2013), in areas where the monthly income of the first quintile is \$60.

The second criticism of progressive pricing is based on the threshold set for the first block of consumption, or lifeline tariff, which is subsidised by the state (Kojima & al, 2014). While this threshold is subject to political pressures, these subsidies are generally meant to enable poor households to access electricity. However, with progressive pricing, this block includes all customers. The first consumption block in a progressive tariff thus tends to be regressive (Foster & Briceño-Garmendia, 2010) because it does not differentiate between the tariffs paid by different power customers, urban or rural, by income level.

2.1.2. The lifeline tariff: a unidimensional definition of energy poverty

In progressive pricing, the subsidized lifeline tariff has been designed to combat energy poverty by ensuring a so-called subsistence level of electricity consumption. The eligibility criteria for a reduced rate are based on total consumption and possible grid connection (Kojima & Trimble, 2016). The lifeline tariff ensures a certain redistributive balance between different customer groups (Briceño-Garmendia & Shkaratan, 2011). The consumption level of the lifeline tariff can thus serve as a first indicator of the energy poverty line.

To date, there is no consensus in the estimation of this threshold. While the most common threshold is 50 kWh per month (Culver, 2017), it is now accepted as varying according to local factors (Pachauri, 2011; Pelz et al., 2018). A final argument suggests using improved energy efficiency to lower the threshold to 30 kWh (Kojima et al., 2016), which is now the SDG7 threshold. The lifeline tariff design thus gives more weight to the quantity of electricity subsidised than to the real consumption of poor households.

At the same time, the size of the first block is not enough to judge the contribution of progressive pricing to improved access. In fact, certain SSA countries set the first block at a threshold of 50 kWh but make a sharp tariff segmentation between the first and second blocks (Briceño-Garmendia & Shkaratan, 2011)[v]. In this case, electricity access remains subsidised for all population levels, but this tariff segmentation creates distinctions between customer groups.

Access failure for the poorest has also led some countries to remove the lifeline tariff from the progressive tariff and let it work separately. This in fact highlights the failure of the redistributive aspect of this pricing.

In SSA, lifeline tariff design faces fundamental contextual elements of consumer behaviour. There are many households that are unable to take advantage of lifeline tariffs due to the inability to settle their bills[vi] or difficulties paying the connection fees to access the grid. On the other hand, tariff structures are based on a hypothesis of scale that assumes the poorest consumers will consume the least. However, when shared meters are used, they deny poor households access to lifeline tariffs as the combined electricity consumption of several households puts them in a higher tariff block (Kojima & Trimble, 2016) and thus prevents the more precise segmentation of residential customers.

The move to prepaid meters also points to the limits of the redistributive nature of progressive tariffs. Prepaid meters are inherently able to take lifeline tariffs into account. Making subsidies possible for the poorest households, however, does not promote access (Jacome & Ray 2018).

In SSA, while the subsistence consumption level for the lifeline tariff should be the best indicator of access, the lack of consistency in the design and implementation of the lifeline tariff has hindered efforts to improve access to electricity.

New unidimensional measures thus connect subsistence electricity consumption to household income level and highlight the rate of effort expended for access (Foster & Bricenio-Garmendia, 2010). Kojima et al. (2016) have shown that median electricity bill makes up 3% of monthly household expenses, with no substantial difference between poor and non-poor households, thus confirming the ability and willingness to pay among the poor. However, for the poorest households, whether rural or urban, this rate increases to 5%. So that the poverty threshold correctly describes the incidence of energy poverty among urban and rural populations, the 5% electricity bill threshold can be used for the poorest households in the first income quintile. With a subsistence consumption level of 30 kWh, the subsidy level for this poverty threshold is $0.10 per kWh. Finally, energy poverty, which is defined by a combination of criteria based on income share and consumption level, tends to homogenise information about access when used in progressive pricing.

However, the tariff approach to energy poverty as defined above poses two problems. On the one hand, given very little progression in household income, the measurement of poor households' electricity access is sensitive to the standard criterion of consumption block: decreasing it may take households out of energy poverty, but this entails restricted energy services and thus limits the opportunities access might offer. On the other hand, only households with the potential to connect to electricity infrastructure that offers the tariff are covered. However, energy poverty is a continuum (Chiappero-Martinetti, 2006) that aggregates those with no access and without access to lifeline coverage.

To improve the representation of tariff energy poverty and its relationship to access, it is thus preferable to learn from multidimensional energy poverty concepts (Nussbaumer et al., 2012) and move to a measurement with two dimensions: to represent a poverty line linked to tariffs, an affordability rate of 5% of household income for a subsistence consumption of 30 kWh; and access rates that reflect populations deprived of access and thus excluded from the lifeline tariff.

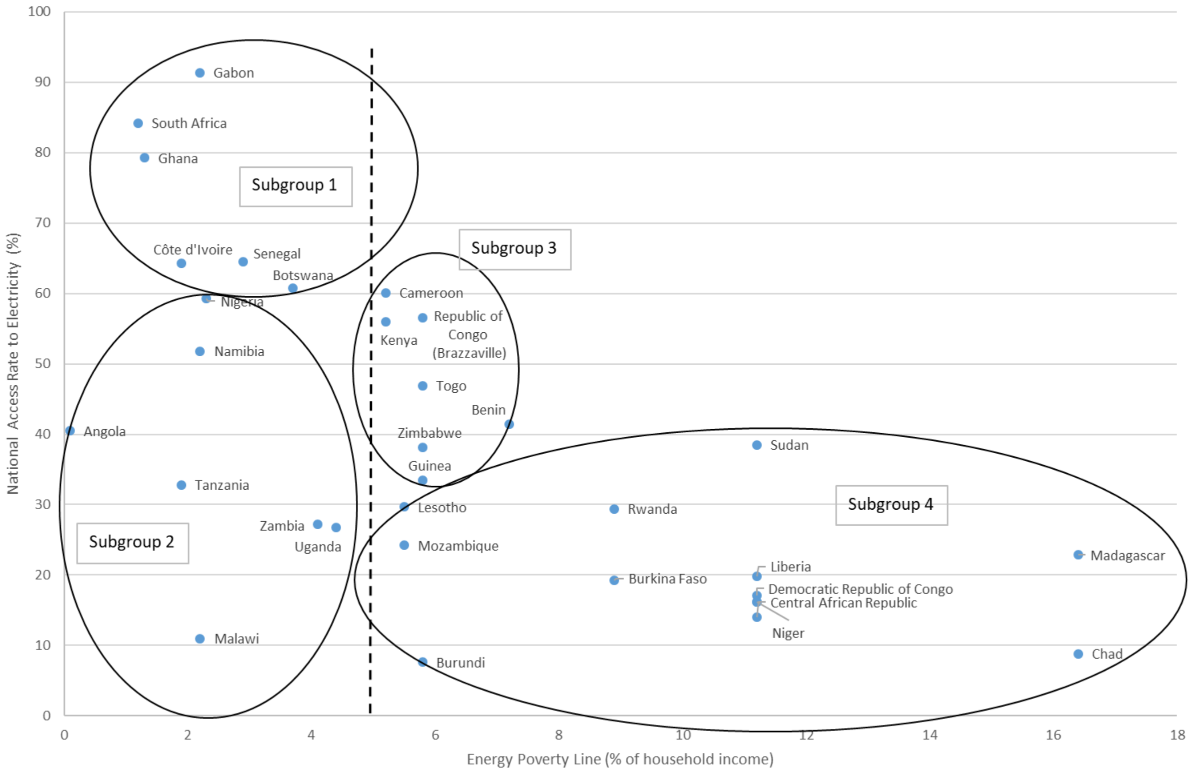


Figure 2. Subsamples from the combination of access rate with the energy poverty indicator of 5% of household income dedicated to energy expenses (2012)

This descriptive combination for SSA countries allows us to create four major categories for the countries in our sample. There are several advantages of this metric. First, it makes it possible to contrast countries' path to access and show the heterogeneity of energy poverty. It then helps differentiate the countries where the lifeline tariff indicates movement toward access in the context of great energy poverty and those countries whose mature pricing policy supports the poorest citizens in accessing electricity. Finally, it enables us to categorise the countries according to the intensity of the subsidies promoting access.

- Classifying the sample

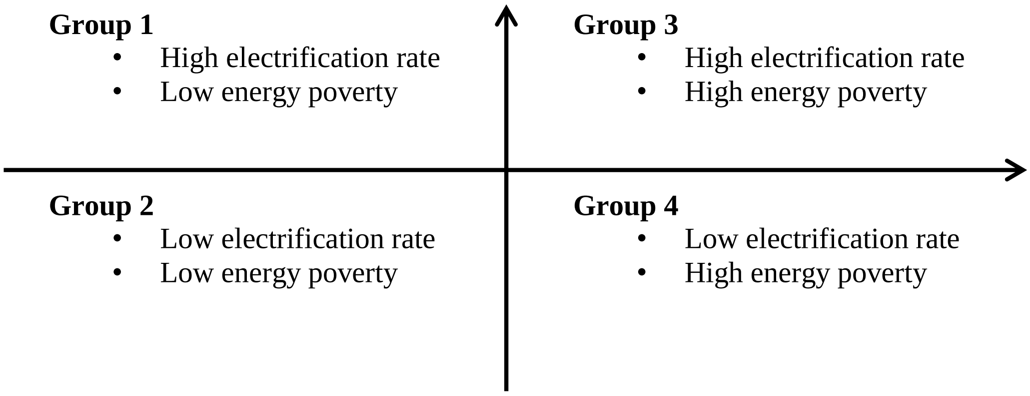


Figure 3. Groups of SSA countries identified by combinations of each country's electrification rate and their energy poverty

In our empirical strategy, lifeline tariffs are accounted for in two ways: the subsidies they provide to the end user in kWh billed and through the metric of energy poverty heterogeneity that they enable us to obtain in our sample.

2.1.3. An allocation of subsidies that disadvantages access

Whatever energy resource is used, public authorities in SSA use subsidies to promote access to energy. They can be allocated to consumption or production, even though in practice it remains difficult to distinguish between both. The various aspects of this massive subsidisation have many implications.

Inasmuch as half of the population at most in SSA has access to electricity, subsidies[vii] are also allocated to fossil fuels to ensure access to nonelectrical energy. Very widespread and simple to implement (Coady et al., 2015), these measures would be both socially and politically difficult to reverse despite their highly regressive nature (Dartanto, 2013). However, a global consensus is emerging that these subsidies should be removed through progressive reforms combining the real cost of fossil fuels with compensation for low-income households (Zinecker et al., 2018). SSA is part of this trend, although social acceptance and confidence in institutions may complicate its implementation.

In terms of access, the advantage of progressive tariffs lies in the possibility of using subsidies to support poor households. Connection fee subsidies are designed to give customers access to on-grid electricity, while consumption subsidies make electricity less expensive for the customers served (Golumbeanu & Barnes, 2013).

These two types of subsidies may or may not be targeted (Komives et al., 2008). Non-targeted subsidies arise when tariff block differentiation does not pass on the marginal cost of providing service to end users. In contrast, targeted subsidies benefit specific groups, like low-income households, households in substandard housing or consumers who use very little electricity. In fact, explicit and targeted quantity subsidies are widespread in SSA (Komives et al., 2005).

In SSA, three-quarters of households with access to electricity belong to the two highest income quintiles, while scarcely 10% of the households in the lower income distribution have access (Komives et al., 2008). Residential consumption subsidies are thus largely allocated to more comfortable urban households. In the end, then, subsidies in the SSA electricity sector are regressive in nature (Foster & Briceño-Garmendia, 2010).

The inability to differentiate between the different blocks in progressive tariffs has led to a loss of revenue for public utilities, estimated at $4 billion per year (Briceño-Garmendia et al., 2008). These tariffs are designed for certain customer categories, especially industrial consumers. The residential sector, which makes up 95% of electricity customers, contributes only 50% of revenue (Foster & Briceño-Garmendia, 2010). Cross-subsidies from large to small consumers or from urban to rural customers to finance rural electrification are frequently unattainable.

2.2. Regressive pricing for productive use: targeting policies in SSA countries

In SSA, the tariff structures remain especially advantageous for productive use of electricity.

2.2.1. Tariff structures and exemptions

Almost 60% of commercial and 50% of industrial companies are offered a linear tariff (Briceño-Garmendia & Shkaratan, 2011) with three distinct parts:

- A fixed monthly fee set according to grid characteristics and independent of consumption. Various taxes may be added to this fee;
- A demand charge defined according to peak demand served. Customers must pay a contractual amount for electricity service even if they do not use the full amount. Demand charges are destined to help cover public utility fixed costs for service provision;
- A volumetric charge, according to the amount of consumption served.

Despite notable differences between countries and types of actors, industrial rates in two-thirds of SSA countries are on average 20 to 30% lower than commercial rates (Briceño-Garmendia & Shkaratan, 2011). The same is true for volumetric charges. Electricity pricing for companies favours productive consumption and increases the regressive benefit for the biggest consumers.

For productive consumers, the price per kWh of electricity sold varies widely between countries due to exemptions from various tariff elements. Thus, according to Briceño-Garmendia & Shkaratan (2011), some twenty SSA countries charge neither a fixed fee nor a demand charge for business and industry. Small industry is most likely to be exempt from these charges (Kojima et al., 2014), constituting a sort of subsidy for commerce and industry.

On the other hand, while electricity companies recoup part of their costs through contract demand charges, these are allocated more to medium and large industrial consumers than to small retail and service businesses (Kojima et al., 2014).

2.2.2. By economic activity

The major electricity consumers tend to be heavy industry companies, targeted by time-of-use tariffs (TOU). This kind of tariff mechanism helps smooth out energy consumption over time as it guarantees financial compensation to consumers if they delay their use to off-peak times[viii]. Frequently, TOU allows for a tariff structure that decreases according to marginal costs and can in fact cause industry to overconsume heavily subsidised electricity (Kojima et al., 2014). In addition, over half of SSA countries are abandoning tariffs differentiated by volume. These tariffs are being replaced by linear rates that vary according to consumption level, even for major electricity consumers (Kojima & Han, 2017).

Governments also benefit from fee exemptions, essentially for public lighting (Kojima & Han 2017). These specific tariffs are generally supported by investment funds dedicated to public lighting or rural electrification[ix]. Another subsidised sector is export agriculture, the leading source of employment in SSA and the primary source of wealth. (Kojima & Han, 2017).

However, the industry that benefits most from these tariffs is mining. This industry is very often the largest purchaser of the energy the utilities produce. Without this demand, utilities would be unable to reinvest in the grid. Several utility companies have in fact developed specific tariffs for the major actors in the mining industry[x]. The electricity rates for these actors are thus much lower than those for retail and service businesses and households, with often highly advantageous contract clauses. Cost comparison is decisive when a mine needs to choose between supplying its own power or connecting to the grid[xi].

Electricity pricing for productive use has attempted to use subsidies to add maximum value to industries with high capital intensity like agro-industry and mines. The insufficient tariffs per kWh produced, however, have worsened the financial situations of power companies, which are increasingly unable to raise sufficient resources for electrification.

In the current electricity tariff structures in SSA, subsidies have turned into strongly regressive tariffs that favour the largest residential and productive consumers even though they were intended to relieve the poorest citizens' lack of electricity access or improve their access. Given the poverty that dominates the access issue, the challenge to these tariff structures is to see how they can better target consumers, the main instrument of their performance.

This literature review provides some key information for our empirical strategy on the role of pricing in access. First, it indicates the elements that need to be considered to explain both rural and urban residential access: pricing structure, number of blocks, lifeline tariffs and connection fees. Second, our review has also helped us see that we have to move away from the homogenized conception of energy poverty in lifeline tariffs. These tariffs must address the most precise and differentiated conditions possible to capture energy poverty heterogeneity; if not by country, then at least by group of countries.

Third, on activity pricing, our review justifies the distinction between industrial and commercial activities.

Our review also suggests the importance of looking at demand-side information: what consumers are prepared to pay to access electricity. Finally, insofar as we define tariff structures as an interface between production and consumption, information on production is needed.

We need all of this information to provide a chronological view of the access trajectories of the different countries, which constitute the observed heterogeneity[xii] that may explain the evolution of national access rates over the whole period. We must accept, however, that some of the variables explaining the evolution of access rates will remain unobserved. These elements require implementing a model that can deal with observed heterogeneity while controlling unobserved heterogeneity that could disrupt any relationships between the access rates and the variables that may explain them.

3. Model

Therefore, to understand the evolution of urban and rural electricity access rates in 33 SSA countries during the period from 1990 to 2012, we use a dynamic panel-data model with random effects. This modelling offers two advantages.

3.1. From data to dependent variables

Panel data uses repeated measures for individuals (countries) over time. The database includes 782 observations. The dataset on energy rates was obtained from annual reports from 33 national regulatory commissions, either directly or from international databases (AICD)[xiii]. Other sources from national regulatory commissions include data on electricity supply and both public and independent (IPP) electricity companies and household surveys providing information about demand (Appendix A).

We will analyse the determining factors for the electricity access rate for urban and rural on-grid households. We have organised these thirteen explanatory variables into three dimensions, supplemented with two control variables.

The first dimension, from our literature review, relates to the specific tariff structure developed by electricity companies in SSA.

- The variables used to describe tariff structures, whether residential or productive, are categorical. Thus, since SSA countries use either simple or IBT pricing for residential tariffs, the residential tariff structure is represented by a dichotomous variable. On the other hand, for productive businesses, the categorisation needs to also include DBT and TOU.
- The number of consumption blocks[xiv] in residential tariff structures. To account for the tariff structure's tendency to target consumers, we have chosen a three-level categorical variable. Linear tariffs dispense with any consumer differentiation; however, progressive pricing of up to three blocks introduces consumer segmentation. Finally, in progressive pricing with more than three blocks, consumer segmentation is the driving force.
- Lifeline tariff and connection fees for households, are continuous variables.

The second group of independent variables is related to electricity production. The liberalisation in the 1990s explains why there are two types of electricity producers on the national markets: public utilities and IPPs. For each country, a continuous variable describes the volume of electricity made available to the end user by producer type, through the tariff structures.

The last group of independent variables is related to demand. Given that the presence of or proximity to the grid is not sufficient to explain the access rate, we need to be able to study the observed and projected demand for electricity separately. However, to do this, the usual willingness-to-pay approach is unavailable to us insofar as we do not have price elasticities of demand and, therefore, demand functions. Consequently, as Choynoswki (2002) suggests, we consider household income the main driver of demand, knowing that the higher the income, the higher the electricity consumption, subject to diminishing returns when basic needs are met. Accordingly, following Kojima et al. (2016) and Dalla Longa & Van Der Zwaan (2021), we use the share of income spent on electricity for each income quintile as an indication of how much households are willing to pay, balancing affordability with the perceived value of electricity. This information is a continuous variable.

We use a balanced database based on the four country groups created using the metric explained in section 2. It provides a global sample with the necessary information for each country group. To the extent that our missing values are missing at random[xv] (Little & Robin, 2019), all this information is assumed to exist over the duration of our study. The database is organised by five categories of variables (See the descriptive statistics in Appendix B).

To monitor the evolution of variables over time, we tested the stationarity of each variable for each group of countries. All of them are stationary. This means that they follow a deterministic trend and therefore the ways they change do not change over time. (Appendix C).

3.2. Panel random-effects models using instrumental variables

Panel data can account for unobserved individual effects, on rate of electricity access here, in order to better analyse the effects of time-varying dependent variables and thus obtain solid estimators. However, we do not know if unobserved individual effects are constant over time. The Hausman test (1981) allows to determine the relationship between individual unobserved heterogeneity and the independent variable and then decide how to proceed: if they are correlated, fixed effects are chosen; if uncorrelated, random effects are selected.

In our case, the Hausman test selects random effects in the four country groups (Appendix D). This selection has two consequences. First, we accept that the random effects are estimated with partial pooling: when a country in one group has weaker data than others, its individual effect will be estimated partially on the more abundant data from other countries of the group. Second, we accept that unobserved individual effects become random variables with a common distribution for all individuals.

One of the advantages of using a random-effects panel is the inclusion of time-invariant variables, but these estimates may be biased because the model does not control for either unobserved heterogeneity or heteroscedasticity.

However, a first regression of the model indicates endogeneity among the independent variables. The Durbin-Wu-Hausman test enabled us to detect a variable with suspected endogeneity, *price per block*. To maintain control of the model and thus preserve unobserved heterogeneity, we move to a panel model with instrumental variables. This solution must be used with all the usual precautions. First, it is necessary to check that the instrument does not explain too small a part of the variation in the endogenous independent variable (Bound et al., 1995). Second, it is necessary to determine the number of instruments sufficient to compensate for the endogeneity of the suspect variable. To correct the endogeneity in *price per block*, we defined an instrumental variable Z_i, *Number of blocks* (all blocks beyond the block 1, i.e. the lifeline tariff), which is designed as a categorical variable. *Price per block* is thus approximated by these instruments, which are correlated with this suspected explanatory variable $(cov\ (Z_i; PB_i) \neq 0)$ but not with the others determinants of independent variables $(cov(Z_i; u_{it}) = 0)$. The results of the first-stage regressions confirm the robustness of *Number of blocks* as instrumental variables drawing on variance tests while over-identification tests conclude that these are the only sufficient instruments (Appendix E).

With these instrumental variables, the two models for urban and rural access can be expressed as follows:

$$y_{it} = X_{it}\beta + \alpha_i + u_{it} + \varepsilon_{it}$$

where

- y_{it} is on-grid urban and on-grid rural households' rate of access;

- X_{it} is the 15 variables detailed in Table 2;

- Random effects are expressed as inter-individual variabilities u_{it} and intra-individual variabilities ε_{it};

- $\propto_i$ refers to constants over time for each variable. We hypothesise that all $\propto_i$ are independently and identically distributed in relation to u_{it}.

In the models, some of the variables are lagged by two increments of time. These delays detect a possible memory effect within each subsample. We target variables that include subsidies:

- Connection fees (CF) remain a key barrier to electricity access, especially for the poor. We apply a memory effect to see whether connection subsidies enable some of the unconnected population to gain access;

- Commercial and industrial tariffs (CT & IT) benefit from subsidies. A memory effect is applied to evaluate the impact of these tariff mechanisms (typically grid supply, priced much lower than self-supply) on the access of these actors;

- First quintile of the population (Q1SIE). Through a memory effect, we analyse whether social tariffs are effective in targeting the poorest part of the population.

For the random-effects regressions, using two-stage least squares analysis, we have chosen to work with the Baltagi estimator (2009) because it allows us to avoid redundant instruments that do not generate additional gains in terms of asymptotic efficiency.

4. Results

Table 2 presents the results for the determinants of rural and urban access for each country subgroup. The level of the R²s provides information on the good explanatory power of the models as well as on how well the unobserved heterogeneity is taken into account.

The heteroscedasticity of the model is controlled by the use of VCE estimators. We also proceed to a check with GMM (Hansen, 1982) (Appendix F). The estimators of the classical model and the GMM model are close and convergent. We can conclude that our model estimators are robust.

To compare the determinants of access among sub-groups, we use the access rates of Group 1 (high rate of access to electricity, low energy poverty) as a benchmark.

The results highlight the regressive nature of pricing policies, which work against electricity access. The results of the model detail the operation of this self-sustaining and widespread mechanism of energy poverty and access as well as location and access. To the extent possible, we will discuss our results in relation to those obtained in the empirical literature even though those results are related to national examples.

4.1. Tariff structure dimension

Overall, for the countries in group 1, residential tariffs meet their access objectives satisfactorily. This pricing of group 1 suggests that rural household access has benefited from the common pattern of subsidising rural access through urban users (RT: significant coefficients of -24.3 and 21.7 for urban and rural households respectively). We can conjecture that pricing supports a transfer between these two household categories insofar as tariff structures seem to have promoted all households' access to electricity (NB: 22.5 for urban households and 23.4 for rural) while sufficiently segmenting urban customers to identify those targeted by the lifeline tariff (2.25). This result confirms that obtained by Komives et al. (2005) on Gabon, which also belongs to this subgroup. The connection fees are not an obstacle to access for urban households (CF: 1.04). This result converges with that of Golumbeanu and Barnes (2013) on Ghana.

The only contradictory result for group 1 is that lifeline tariffs seem not to target enough poor rural households to improve access (-0.79). Moreover, these households do not seem to benefit from supplementary access assistance like rural electrification funds (Peters et al., 2019). This suggests that a differentiation between urban and rural populations in lifeline tariffs would promote access of rural populations and thus increase the critical mass of users. In this case, the use of existing infrastructure would minimise the opportunity cost for access.

Country Groups	1 **High access rates** **Low energy poverty**		2 **Low access rates** **Low energy poverty**		3 **High access rates** **High energy poverty**		4 **High access rates** **Low energy poverty**	
Dependent variables: Access Rates	y = Urban (UA)	y = Rural (RA)	y = Urban (UA)	y = Rural (RA)	y = Urban (UA)	y = Rural (RA)	y = Urban (UA)	y = Rural (RA)
Independent variables								
1. Pricing								
Residential Tariff (RT)	-24.340 ***	21.674 ***	-37.212 ***	9.641**	7.656 ***	-15.458 ***	-9.201	-3.583 **
	(1.902)	(8.069)	(3.750)	(-0,963)	(2.274)	(1.327)	(5.774)	(1.041)
Price per block > Lifeline corrected by instrument Number of blocks (NB)	22.508 ***	23.437 ***	16.737 ***	13.351***	-15.720 ***	-1.327 ***	1.907	-3.339 ***
	(1.311)	(4.559)	(1.872)	-0,556	(1.677)	(0.978)	(2.128)	(0.307)
Lifeline Tariff (LT)	2.250 ***	-0.798 **	2.248 ***	0.847***	0.365	1.327 ***	-1.933 ***	-0.030
	(0.124)	(0.417)	(0.268)	(0.075)	(0.351)	(0.205)	(0.061)	(0.019)
Connection Fee (CF)	1.038 ***	0.407	-0.076 ***	-0.002	0.213 ***	0.054	0.027	-0.028 *
	(0.394)	(0.883)	(0.060)	(0.018)	(0.072)	(0.042)	(0.103)	(0.017)
Connection Fee-1 (CF-1)	-0.056	0.023	-0.002	-0.003	0.003	0.00004	0.005	0.001
	(0.484)	(1.026)	(0.061)	(0.022)	(0.090)	(0.052)	(0.060)	(0.010)
Connection Fee-2 (CF-2)	-0.472	-0.503	-0.016	-0.020	0.061	0.014	0.076 *	0.010
	(0.336)	(0.743)	(0.044)	(0.015)	(0.066)	(0.038)	(0.041)	(0.006)
Commercial Tariff (CT)	-31.491 ***	6.907 ***	-13.531 ***	-3.830***	0.365	3.419	16.855 ***	-0.157
	(3.045)	(2.168)	(1.697)	(0.484)	(0.351)	(2.307)	(3.227)	(0.529)
Commercial Tariff-1 (CT-1)	0.139	-0.141	-0.193	-0.143	0.605	0.464	0.011	-0.099
	(3.510)	(0.359)	(1.258)	(0.437)	(4.372)	(2.551)	4.048	(0.722)
Commercial Tariff-2 (CT-2)	-1.931	-1.682 ***	-1.732 *	-1.185***	5.006	5.031 ***	3.015	-0.449
	(2.456)	(0.317)	(0.963)	(0.329)	(3.263)	(1.903)	(2.832)	(0.498)
Industrial Tariff (IT)	20.770 ***	11.883 ***	0.352	-4.550***	-8.873 ***	-4.483 ***	-10.758 ***	0.056
	(2.020)	(4.678)	(1.710)	(0.556)	(2.737)	(1.597)	(3.067)	(0.498)
Industrial Tariff-1 (IT-1)	-0.245	0.064	0.672	0.208	-0.346	-0.254	-0.095	0.060
	(2.596)	(4.585)	(1.999)	(0.639)	(2.888)	(1.685)	(2.945)	(0.445)
Industrial Tariff-2 (IT-2)	0.211	-0.170	5.401 ***	1.899 ***	-2.151	-2.444 **	3.015	0.311
	(1.751)	(3.380)	(1.467)	(0.481)	(2.111)	(1.231)	(2.832)	(0.304)
2. Production								
Public Utility (PU)	-0 .003 ***	-0.0005 **	-0.002 ***	-0.0005***	0.017 ***	0.011 ***	-0.006 ***	0.001 *
	(0.0003)	(0.0002)	(0.001)	(0.0002)	(0.002)	(0.001)	(0.002)	(0.000)
Independent Power Producer (IPP)	0.019 ***	0.0002	-0.003 ***	0.0002	0.008	-0.019 ***	-0.084 ***	-0.015 ***
	(0.005)	(0.0003)	(0.001)	(0.0003)	(0.008)	(0.005)	(0.004)	(0.001)

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Continuation of the table

Country Groups	1 **High access rates** **Low energy poverty**		2 **Low access rates** **Low energy poverty**		3 **High access rates** **High energy poverty**		4 **High access rates** **Low energy poverty**	
Dependent variables: Access Rates	y = Urban (UA)	y = Rural (RA)	y = Urban (UA)	y = Rural (RA)	y = Urban (UA)	y = Rural (RA)	y = Urban (UA)	y = Rural (RA)
3. Share of income in electricity (SIE) by income quintile as an indication of how much households are willing to pay for access								
Q1SIE	12.834 *** (1.631)	-38.866 *** (1.075)	25.434 *** (2.763)	-38.866 *** (1.075)	-144.898 *** (15.663)	-144.001 *** (15.667)	-10.960 *** (2.104)	0.947 ** (0.482)
Q1SIE-1	0.019 (0.551)	-0.009 (0.309)	0.070 (1.199)	-0.009 (0.309)	0.115 (1.740)	0.116 (1.740)	0.048 (1.015)	-0.003 (0.189)
Q1SIE-2	0.151 (0.381)	-0.099 (0.210)	0.697 (0.818)	-0.099 (0.210)	2.702 ** (1.252)	2.706 ** (2.706)	-0.225 (0.717)	-0.033 (0.130)
Q2SIE	-17.003 *** (2.285)	14.263 *** (0.791)	-24.214 *** (2.373)	14.263 *** (0.791)	311.488 *** (36.370)	308.937 *** (36.381)	27.883 *** 2.378	-1.649 *** (0.571)
Q3SIE	8.930 *** (1.140)	16.057 *** (0.373)	2.266 ** (1.091)	16.057 *** (0.373)	-267.540 *** (32.733)	-264.856 *** (32.744)	-10.371 *** (0.645)	-0.050 (0.121)
Q4SIE	0.620 *** (0.254)	2.801 *** (0.106)	-6.882 *** (0.290)	2.801 *** (0.106)	173.939 *** (20.406)	172.284 *** (20.412)	-8.258 *** (0.587)	0.461 *** (0.139)
Q5SIE	-3.128 *** (0.454)	- -	- -	- -	-74.382 *** (8.304)	-73.795 *** (8.306)	2.909 *** (0.229)	-0.018 (0.044)
Control variables								
Ln POPULATION	2,523 *** (0.753)	2,665 *** (0.714)	2,665 *** (0.714)	1.853 *** (0.616)	2,824 *** (0.580)	2,536 *** (0.459)	2.291 *** (1.114)	1.083 *** (0.246)
Human Development Index (HDI)	-7.953 ** (3.972)	1.695 ** (0.850)	3.490 (2.229)	1.695 ** (0.850)	27.633 *** (6.087)	-10.433 *** (4.097)	-4.072 (3.492)	0.999 * (0.579)
Constant	60.537 *** (2.614)	7.455 *** (8.154)	51.965 *** (2.451)	-17.275 *** -0,755	26.868 *** (3.466)	-7.783 *** (2.838)	60.071 *** (2.547)	5.246 *** (0.633)
Obs	161	161	161	161	184	184	276	276
R-squared	0.8398	0.6533	0.9735	0.9837	0.8983	0.7440	0.7855	0.7376

Table 1. Results obtained from the random-effects panel model with instrumental variables (second-stage regression)
(Standard deviation with heteroscedasticity errors corrected)
(Significance * $p \leq 0.10$, ** $p \leq 0.05$, *** $p \leq 0.01$)

According to the model, in group 2 (low access rate, low poverty rate), like in group 1, both household categories gain access, and the residential tariff structure (NB: 16.7 urban and 13.3 rural) is sufficiently effective to ensure the transfer of urban funds (RT: -37.2) to rural access (RT: 9.6). The subsidised level plays its role satisfactorily (LT: 2.2 urban and 0.8 rural). Nevertheless, these results should be interpreted with caution given the weight of countries with extractive industries in this subsample. Banerjee et al. (2015) point out the role of anchor consumer played by mines in the development of the power system. Thus, connection fees (CF urban: -0.076) seem to indicate the electricity system favours industrial consumption over household access.

The situation is different in groups 3 and 4. In both cases, the model states that the residential tariff hinders rural access (RT: -15.4 for group 3 and -3.6 for 4) and promotes urban access only in group 3 (RT urban: 7.6; group 4: -9.2). This result suggests that in these poorest economies, robust access only involves certain urban populations. The application of tariff structures in these groups arguably works against the objectives being pursued. In fact, in group 3, progressive pricing is most common, but the energy poverty level is an obstacle to the consumer segmentation this tariff structure would imply. In group 4, linear pricing is most common, but the prices charged remain beyond the means of most households. Lifeline tariffs show mixed results. They slightly improve rural access in group 3 (LT: 1.3). This result is in line with a finding for Kenya which mentions that besides a lifeline tariff, urban rates are set higher to cross-subsidise rural customers (Scott and Pickard, 2018). However, lifeline tariffs work against their objectives for urban populations in group 4 (LT: -1.9). In both groups, connection fees have a very weak explanatory power but act positively for urban households in group 3 (CF: 0.2) and negatively for rural households in group 4 (CF: -0.03).

The model helps show that residential pricing creates a sharp divide between the groups of countries. When there is low energy poverty, this pricing lets urban households finance rural access through cross-subsidised financing and thus can contribute to the expansion of rural electrification. Tariff structures, including lifeline tariffs, tend to be effective to this end. However, in countries with high energy poverty, pricing favours urban access at the expense of rural access. Lifeline tariffs are unable to counter this effect, even though a certain level of electrification provides eligible rural households with modest access. For all these groups, it can be argued that lifeline tariffs are able to open access to a certain number of consumers. But this is a fragile achievement: lowering them would only have a small effect on access (Komives et al., 2005) while this pricing instrument fails to reach the poorest, whatever the threshold is. Finally, our results highlight lifeline tariffs' limited scope of action, beyond which other ways of subsidising access would be more effective. This certainly points to a dividing line between the suitability of subsidising on-grid or decentralized solutions.

The model's tariff structures for productive activities point to a trend of favouring industrial activities. Thus, for group 1, pricing has promoted the growth of urban industry (IT*:* 20.7), which has benefited from a transfer from commercial activities (CT*:* -31,5), while promoting both commerce (CT: 6.9) and industry (IT: 11.9) in rural areas. This includes an improved impact of rural business pricing over time (from CT-2: -1.7 to CT: 6.9). South Africa skews the group's results toward a development model, focusing on industry and urban, that may not be completely representative. In group 2, tariffs also benefit industry (IT-2: 5.4) at the expense of the commercial sector (CT: -13.5). Extractive industries, which are representative of this group, are clearly favoured. The *Industrial Tariff* variable, however, loses its significance due to the weight of Nigeria in this subsample. These results are nevertheless only useful for urban access. In rural areas, tariff structures work against both industrial and commercial activities. Indeed, while pricing is always unfavourable to commercial activities (CT-2: -1.2 and CT: -3.8), the contribution of rural industries to access goes from positive (IT-2: 1.9) to negative when time is factored in (IT: -4.6). This could mean that pricing causes a transfer from rural to urban industries.

In contrast, in groups 3 and 4, tariff structures work against urban industry (IT: -8,9 and -10,8) with no systematic benefit to commercial activities (CT: 16.85 for group 4). Rural industry is not supported by the tariff structures (IT-2: -2.44 and IT: -4.48 for group 3), and the results for rural commercial activity are ambiguous (CT-2: 5.03). The positive contributions of tariff structures for productive sectors to access that was observed in group 1 and somewhat in group 2 is completely lacking in the other groups. This would suggest that industrial development is still inadequate and thus does not enable tariff structures to support these sectors, despite high subsidies.

The tariff structure dimension of our model highlights contrasts between the country groups. While differentiating subsidised rates between urban and rural populations is a possible solution for the most advanced group in access, everywhere else, subsidising rural populations through the grid does not appear to be a solution for increasing their access. This suggests a dividing line between on-grid and decentralized access that needs to be identified to reallocate subsidies and improve access. Productive tariffs promote industry with clear differentiation in favour of urban industry.

4.2. The production dimension

According to the model, for all groups, the production variables have a very weak explanatory power for access. The utilities' ineffectiveness in serving customers can be found everywhere. The deregulation of suppliers through IPPs does not counterbalance this ineffectiveness, except for group 1 (IPP: 0.019). These results once again confirm the inadequacies of the centralised electricity supply in promoting rural electrification (Vessat, 2020).

4.3. The share of income in electricity dimension

As seen above, since the willing to pay is obtained through the share of household income spent on electricity (SIE), it is considered the amount that households would be prepared to pay to have access to electricity.

In the model, only the poorest urban households of groups 1 and 2 have a positive SIE (Q1SIE 12.8 and 25.4), directly linked with their access to lifeline tariffs. In both cases, lifeline tariffs seem to act as a learning effect in terms of bill payment and use of electricity services. In contrast, a different pattern emerges for rural populations. In groups 2 and 3, lifeline tariffs appear to influence access positively (LT: 0.85 and 1.3), but household income level is not enough to trigger the learning effect (Q1SIE -38.86 and -144.001). Otherwise, in urban households in groups 3 and 4, as for all rural households in the other groups, SIE is negative for the first quintile, and the subsidised rates seem to be powerless to trigger access. The model highlights that for this quintile, household income level is the major obstacle to access, and lifeline tariffs contribute little, if at all. This remains the case even though many studies agree that households allocate a large share of their budget to energy expenses that is, in any case, higher than the cost of electricity for this income level (Winkler, 2011; Briceño-Garmendia & Shkaratan, 2011; Lenz et al., 2017).

In groups 1 and 2, the negative urban SIE in the second quintile (Q2SIE: -17.003 and -24.2) shows that residential pricing is too high for these consumers to consider buying electricity without aid. In these groups, which have the lowest energy poverty rate, the second income quintile in urban areas thus loses the pricing that would enable access. This result confirms that lifeline tariffs cover poor grid consumers but do not target the poor correctly (Komives et al., 2005). We would add that this targeting problem includes but does not address those consumers whose income is just above that covered by the lifeline tariff, thus destabilising the internal equilibrium of progressive pricing. Apart from urban households in the second quintile, all households, urban or rural, have a positive SIE. Lifeline tariffs do not support this result (except for rural households in groups 2 and 3) This can mean that residential pricing also misses the mark in this case and that the financial ability to pay an electricity bill is likely to come up against supply limitations, regardless of the area.

For households in quintile 3 and over, the model's results for SIE are positive or negative, with no obvious pattern. A positive SIE from Q3 to Q4 in rural areas underlines that these households can pay for both access to the grid and electricity but are deprived of both.

The negative SIE of the highest income group in both urban and rural areas of all groups in the model should also be noted. For this quintile, consumer expectations are the same in urban and rural areas and certainly indicate a need for service quality improvements. The possibility to substitute other power sources for on-grid access at this income level has already been pointed out (Perez-Ariaga et al., 2019). In contrast, a positive SIE in an urban area in group 4 (Q5SIE: 2.9) indicates a population with the ability to pay but most likely still off-grid.

In the end, the model underlines that the economic conditions of different population groups limit or promote access to on-grid electricity more than does location. Urban residential pricing that is not sufficiently segmented has questionable effects. When a focus on pricing to help the poorest gain access is successful, this only reveals a new target group that has been ignored by current tariffs. This analysis of the SIE argues for a more dynamic approach to residential tariffs that is attentive to shifts in energy poverty thresholds. To do so, the design of lifeline tariffs should integrate knowledge of consumption patterns as well as resource requirements or location criteria to increase their adaptability. Another element would be expectations for the grid: the extensive approach to electrification only rarely seeks to create a denser population of poor customers around existing infrastructure even though the sustainability of progressive pricing depends on its ability to increase the critical mass of consumers.

5. Conclusion and Policy Implications

The literature has analysed the effect of pricing on household and productive grid access in three ways, most often addressed separately. Our contribution is the joint consideration of the factors explaining access, i.e., supply and its organisation, demand and its dynamics, and the share of income in electricity used as a proxy of households willing to pay. Furthermore, our paper develops an approach to the access issue by country group rather than by country.

For SSA households connected to the grid, the inherent limits to electricity access emerge more from their economic conditions, especially their poverty level, than from their location. However, poverty is not the only obstacle to accessing electricity. The ineffectiveness of the tariff structures provides an important explanation for the continued massive lack of access.

- First, progressive tariff structures turn out to be regressive, especially at the first consumption block or lifeline tariff. However, the sensitivity of this regressive nature decreases when access is improved and better distributed between urban and rural consumers. This means that these conditions favour stabilising consumer behaviour, which in turn stabilises the revenue of utilities;
- Second, the regressive pricing implemented by power companies in SSA tends to greatly benefit productive activities;
- Third, household poverty at the lowest income level confirms the direct link between monetary poverty and access. Nevertheless, we observed shifts in the threshold consumption for these

households, suggesting that the untapped opportunity to carefully targeted electricity pricing could be implemented in urban and rural areas to match consumer targeting with improved access.

The heterogeneity of the subgroups suggests, moreover, that there are variances in the contributions made by policies promoting access. However, the current pricing instruments are unable to significantly improve access for many citizens. The trade-off between the power companies' need to cover their costs and an expansion of electrification thus seems destined to last. However, decreasing the regressive nature of pricing could be achieved under certain conditions.

- Better segment the progressive tariff blocks by creating more significant price differences. Since electricity consumption remains a function of income, the tariff for higher blocks could be raised, working with tenable hypotheses on the percentage of income spent on electricity. Substitution effects could be moderated by higher quality energy services.
- Develop a lifeline tariff, which now characterises the first consumption block and has become a source of exclusion for consumers in the next block, based not on the volume of electricity used but on a basket of energy services designed to help households stabilise their current income and improve it in the future. An evolving lifeline tariff could be paired with a temporary exemption from connection fees.
- Rein in the benefits to large businesses and industry from regressive rates.
- Use an abundance of caution in trying to replicate successful tariff reform from one country to others. The way that additional gains in access are achieved seem to be sensitive to general access conditions of each country group. For example, while encouraging progressive pricing seems necessary in group 1, it may not apply to countries in groups 3 and 4. Similarly, it would be useful to distinguish between rural and urban lifeline tariffs, and thus differentiate use of subsidies, in country groups with more advanced access, but this would not achieve any access gains in groups 3 and 4. Similarly, it would improve the allocations of subsidies between on-grid and decentralized power to set a threshold beyond which subsidies of on-grid access do not achieve any access gains, if the conditions of this reallocation could be defined on a territorial basis, even within a country.

Finally, we would like to stress several aspects where contributions could be made to improve this work.

Consistent with what has been observed, the paper has looked at stable tariff structures over time. Thus, the sensitivity of access to changes in the tariff structures was not studied. Making tariff structures more dynamic could undoubtedly lead to better segmentation of consumers, particularly where progress through on-grid access is now well established. But probably for all countries, it could also lead to better adaptation to the differentiated increase in demand according to household income and consequently, a better use of cross-subsidies between categories of consumers.

In addition, the metric introduced to contrast energy poverty drawing on the lifeline tariff is resolutely national. As a result, our classification does not capture the disparities in energy poverty within each country. To the extent that energy policies are implemented at the national level, any effort to segment consumers in order to improve the targeting of tariffs likely requires developing a differentiated approach to domestic energy poverty to improve access. Transposed within a country, the quadrants of our classification can perhaps offer a first basis.

Lastly, since our study focuses on households connected to the grid, it excludes rural off-grid electrification. The use of off-grid power in SSA has led development actors to look for new models (Bhattacharyya, 2013; Lenz et al., 2017) focusing on unconventional schemes to expand the electricity supply (Sokona et al., 2012; Perez-Ariaga et al., 2019; Falchetta et al., 2021), especially decentralised production solutions based on renewables. However, these solutions, unlike conventional centralised grid systems, assign a new role to demand and its dynamics, where tariffs like pay-as-you-go might be only a first step.

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Appendix A. Data sources

Country	National regulators	Country	National regulators
Angola	Regulatory Institute of the Electrical Sector	Malawi	Malawi Energy Regulatory Authority
Benin	Autorité de régulation de l’électricité (ARE)	Mali	Commission de Régulation de l’Electricité et de l’Eau
Botswana	Botswana Energy Regulation Authority	Mozambique	Energy Regulatory Authority
Burkina Faso	Autorité de Régulateur du Sous-Secteur de l’Electricité	Namibia	Electricity Control Board
Burundi	L’Agence de Régulation des Secteurs de l’Eau potable, de l’Electricité et des Mines	Niger	Autorité de régulation du secteur de l’Energie
Cameroon	Agence de régulation du secteur de l’électricité	Nigeria	Nigerian Electricity Regulatory Commission
Chad	Autorité de régulation du secteur de l'énergie électrique	Uganda	Electricity Regulatory Authority
Congo Brazzaville	Agence de régulation du secteur de l’électricité	RDC	Autorité de régulation du secteur de l’électricité
Côte d’Ivoire	Autorité nationale de régulation du secteur de l’électricité	Rwanda	Autorité de Régulation des Services Publics du Rwanda
Ethiopia	Ethiopian Electric Power Establishment	Senegal	Commission de régulation du secteur de l’électricité
Gabon	Agence de Régulation du Secteur de l’Eau potable et de l’Energie électrique	South Africa	National Energy Regulator of South Africa
Ghana	Public Utilities Regulatory Commission + Energy Commission	Sudan	Electricity Regulatory Authority
Guinea	Autorité de Régulation du Secteur de l’Eau et de l’Electricité	Tanzania	Energy and Water Utilities Regulatory Authority
Kenya	Energy Regulatory Commission	Togo	Autorité de Réglementation du Secteur d’Electricité
Lesotho	Autorité de l’électricité du Lesotho	Zambia	The Energy Regulation Board
Liberia	Liberia Electricity Regulatory Commission	Zimbabwe	Zimbabwe Energy Regulatory Authority
Madagascar	Office de Regulation de l'Electricité		

1.1. Complete list of electricity market regulation authorities in SSA countries

Variables	Code	Sources
I. Access category		
1. Urban access rate	UA	- https://www.iea.org/energyaccess/database https://www.iea.org/publications/freepublications/publication/WEO2017SpecialReport_EnergyAccessOutlook.pdf
2. Rural access rate	RA	
II. Tariff categories		
3. Residential tariff	RT	- Africa Country Infrastructure Diagnostic Data Base (2009): http://infrastructureafrica.opendataforafrica.org/dqrkuif/about - Briceño-Garmendia (2011):http://documents.worldbank.org/curated/en/234441468161963356/Power-tariffs-caught-between-cost-recovery-and-affordability - Eberhard & al (2017) - Kojima & al (2016): https://openknowledge.worldbank.org/handle/10986/25091
4. Number of blocks	NT	
5. Lifeline tariff	ST	
6. Connection fee	FC	
7. Commercial tariff	CT	
8. Industry tariff	IT	
III. Production category		
9. Public utilities	HP	Africa Country Infrastructure Diagnostic Data Base (2009): http://infrastructureafrica.opendataforafrica.org/dqrkuif/about
10. IPP	IPPP	

IV. Share of income in electricity (SIE)category by income quintile		
11. Q1	Q1SIE	- Africa Infrastructure Country Diagnostic Power Tariff. 2009. AICD Database: http://dataportal.opendataforafrica.org/data/#topic=Energy - Kojima & al (2016): https://openknowledge.worldbank.org/handle/10986/25029
12. Q2	Q2SIE	
13. Q3	Q3SIE	
14. Q4	Q4SIE	
15. Q5	Q5SIE	
V. Control variables		
16.Population	POP	https://donnees.banquemondiale.org/indicateur/NY.GDP.PCAP.PP.CD https://donnees.banquemondiale.org/indicator/SP.POP.TOTL
17. Human Development Index	HDI	Human Development Reports (UNDP) http://hdr.undp.org/en/data

1.2. Sources for variables

Appendix B – Descriptive statistics for the 4 country groups identified by combinations of each country’s electrification rate and their energy poverty

Group 1: High access rates - Low energy poverty										
Variables and codes	**Unit of measure**	**Type of variable**	**Categories**	**6 Countries -** Botswana, Gabon, Ghana, Côte d’Ivoire, Senegal, South Africa						
				Obs	**Average**	**Min**	**Max**	**σ Total**	**σ Between**	**σ Within**
Dependent Variable : Access Rate (2)										
Urban (UAR)	%	Continuous	-	161	80.48	40.1	99.1	14.11	4.25	13.48
Rural (RAR)	%	Continuous	-	161	27,81	2.2	66.9	13.04	6.93	11.13
Independent variables (13) ***1. Pricing***										
Residential Tariff (RT)	Numerical	Dichotomous	0 = Linear 1= IBT	46 115	2/6 4/6	0 0	2 4	0.45	0	0.45
Number of blocks (NB)	Numerical	Categorial	0 = 1 block 1 = [1-3] blocks 2 = [3-11] blocks	46 46 69	2/6 2/6 2/6	0 0 0	2 2 2	0.84	0	0.84
Lifeline tariff (LT)	Cents $ /kWh	Continuous	-	161	7.38	0	18.6	5.35	0.40	5.34
Connection fee (CF)	$ /kW/year	Continuous	-	161	13.56	0	24.4	9.88	0	9.88
Commercial Tariff (CT)	Numerical	Categorial	0 = Linear rate 1 = IBT 2 = DBT 3 = TOU	92 23 23 23	3/6 1/6 1/6 1/6	0 0 0 0	3 1 1 1	1.07	0	1.07
Industrial Tariff (IT)	Numerical	Categorial	0 = Linear rate 1 = IBT 2 = DBT 3 = TOU	92 0 0 69	3/6 0 0 3/6	0 0 0 0	3 0 0 3	1.49	0	1.49
2. Production										
Public utility (PU)	GWh	Continuous	-	161	5 983.64	132	42 784	12 805.6	973.19	12 769.96
IPP (IPP)	GWh	Continuous	-	161	284.40	0	2 036	556.59	109.83	546.06
3. Share of income in electricity by income quintile										
Q1 (Q1SIE)	Expenses ($/month)	Continuous	-	161	3.43	0	8	2.27	0	2.27
Q2 (Q2SIE)			-	161	6.71	0	13	4.04	0	4.04
Q3 (Q3SIE)			-	161	8.29	0	17	5.22	0	5.22
Q4 (Q4SIE)			-	161	12.42	0	21	8.34	0	8.34
Q5 (Q5SIE)			-	161	12	0	27	8.27	0	8.27
Control variables (2)										
Population (POP)	Ln millions	Continuous	-	161	16.01	6.86	17.79	1.44	0.30	1.41
HDI (HDI)	Numerical	Continuous	-	161	0.48	0.33	0.69	0.12	0.03	0.12

Group 2 : Low access rates - Low energy poverty										
Variables and codes	**Unit of measure**	**Type of variable**	**Categories**	**7 Countries -** Angola, Nigeria, Namibia, Malawi, Tanzania, Uganda, Zambia						
				Obs	**Average**	**Min**	**Max**	**σ Total**	**σ Between**	**σWithin**
Dependent Variable : Access Rate (2)										
Urban (UAR)	%	Continuous	-	161	59.21	19.30	94.10	22.68	4.26	22.29
Rural (RAR)	%	Continuous	-	161	7,43	0.10	34.40	9.74	1.64	9.61
Independent variables (13) 1. *Pricing*										
Residential Tariff (RT)	Numerical	Dichotomous	0 = Linear 1= IBT	46 115	2/7 5/7	0 0	2 5	0.45	0	0.45
Number of blocks (NB)	Numerical	Categorial	0 = 1 block 1 = [1-3] blocks 2 = [3-11] blocks	46 92 23	2/7 4/7 1/7	0 0 0	2 4 1	0.64	0	0.64
Lifeline tariff (LT)	Cents $ /kWh	Continuous	-	161	10.15	1.05	23.74	6.81	0.75	6.77
Connection fee (CF)	$ /kW/year	Continuous	-	161	32.1	0	97	29.81	0	29.81
Commercial Tariff (CT)	Numerical	Categorial	0 = Linear rate 1 = IBT 2 = DBT 3 = TOU	138 23 0 0	6/7 1/7 0/7 0/7	0 0 0 0	6 1 0 0	0.35	0	0.35
Industrial Tariff (IT)	Numerical	Categorial	0 = Linear rate 1 = IBT 2 = DBT 3 = TOU	138 23 0 0	6/7 1/7 0/7 0/7	0 0 0 0	6 1 0 0	0.35	0	0.35
2. *Production*										
Public utility (PU)	GWh	Continuous	-	161	360.79	0	1 400	300.42	169.23	250.38
IPP (IPP)	GWh	Continuous	-	161	264.55	0	1 868	581.75	24.04	581.28
3. *Share of income in electricity by income quintile*										
Q1 (Q1SIE)	Expenses ($/month)	Continuous	-	161	1.57	0	6	2.14	0	2.14
Q2 (Q2SIE)			-	161	1.71	0	7	2.44	0	2.44
Q3 (Q3SIE)			-	161	1.86	0	7	2.54	0	2.54
Q4 (Q4SIE)			-	161	2.86	0	8	3.41	0	3.41
Q5 (Q5SIE)			-	161	6.14	0	21	7.92	0	7.92
Control variables										
Population (POP)	Ln millions	Continuous	-	161	16.65	14.15	18.95	1.21	0.18	1.20
HDI (HDI)	Numerical	Continuous	-	161	0.45	0.31	0.61	0.07	0.04	0.06

Group 3: High access rates - High energy poverty										
Variables and codes	**Unit of measure**	**Type of variable**	**Categories**	**8 countries -** Benin, Cameroon, Gambia, Guinea, Kenya, Republic of the Congo, Togo, Zimbabwe						
				Obs	**Average**	**Min**	**Max**	**σ Total**	**σ Between**	**σ Within**
Dependent Variable : Access Rate (2)										
Urban (UAR)	**%**	**Continuous**	-	184	58.90	23.2	88.6	16.05	4.81	15.34
Rural (RAR)	**%**	**Continuous**	-	184	8.64	0.1	25.7	6.24	2.77	5.62
Independent variables (13) 1. *Pricing*										
Residential Tariff (RT)	Numerical	Dichotomous	0 = Linear 1= IBT	23 161	1/8 7/8	0 0	1 7	0.33	0	0.33
Number of blocks (NB)	Numerical	Categorial	0 = 1 block 1 = [1-3] blocks 2 = [3-11] blocks	23 92 69	1/8 4/8 3/8	0 0 0	1 4 3	0.66	0	0.66
Lifeline tariff (LT)	Cents $ /kWh	Continuous	-	184	10.07	2.07	17.2	4.08	0.13	4.08
Connection fee (CF)	$ /kW/year	Continuous	-	184	23.89	0	78.9	32.57	0	32.57
Commercial Tariff (CT)	Numerical	Categorial	0 = Linear rate 1 = IBT 2 = DBT 3 = TOU	115 69 0 0	5/8 3/8 0/8 0/8	0 0 0 0	5 3 0 0	0.49	0	0.49
Industrial Tariff (IT)	Numerical	Categorial	0 = Linear rate 1 = IBT 2 = DBT 3 = TOU	138 46 0 0	6/8 2/8 0/8 0/8	0 0 0 0	6 2 0 0	0.43	0	0.43
2. *Production*										
Public utility (PU)	GWh	Continuous	-	184	426.58	0	2 067	642.92	49.47	641.09
IPP (IPP)	GWh	Continuous	-	184	72.15	0	300	80.29	33.06	73.45
3. *Share of income in electricity by income quintile*										
Q1 (Q1SIE)	Expenses ($/month)	Continuous	-	184	1.25	0	7	2.39	0	2.39
Q2 (Q2SIE)			-	184	1.50	0	7	2.46	0	2.46
Q3 (Q3SIE)			-	184	1.88	0	7	2,98	0	2.98
Q4 (Q4SIE)			-	184	3	0	15	5.09	0	5.09
Q5 (Q5SIE)			-	184	4.13	0	21	6.90	0	6.90
Control variables										
Population (POP)	Ln millions	Continuous	-	184	15.90	13.77	17.61	0.93	0.17	0.92
HDI (HDI)	Numerical	Continuous	-	184	0.44	0.28	0.57	0.06	0.03	0.05

Group 4: Low access rates - High energy poverty										
Variables and codes	**Unit of measure**	**Type of variable**	**Categories**		**12 countries -** Burkina Faso, Burundi, Chad, Lesotho, Liberia, Madagascar, Mozambique, Niger, Central African Rep., Democratic Rep. of the Congo, Rwanda, Sudan					
				Obs	**Average**	**Min**	**Max**	**Total**	**σ Between**	**σ Within**
Dependent Variable : Access Rate (2)										
Urban (UAR)	**%**	Continuous	-	276	40.68	0.1	68	18.27	5.23	17.54
Rural (RAR)	**%**	Continuous	-	276	4.08	0.1	17.8	3.89	1.93	3.39
Independent variables (13) *1. Pricing*										
Residential Tariff (RT)	Numerical	Dichotomous	0 = Linear	161	7/12	0	7	0.49	0	0.49
			1 = IBT	115	5/12	0	5			
Number of blocks (NB)	Numerical	Categorial	0 = 1 block	161	7/12	0	7	0.65	0	0.65
			1 = [1-3] blocks	92	4/12	0	4			
			2 = [3-11] blocks	23	1/12	0	1			
Lifeline tariff (LT)	Cents $ /kWh	Continuous	-	276	13.10	0	34	9.16	0.32	9.15
Connection fee (CF)	$ /kW/year	Continuous	-	276	20.73	0	92.1	28.86	0	28.86
Commercial Tariff (CT)	Numerical	Categorial	0 = Linear rate	184	8/12	0	8	0.47	0.02	0.47
			1 = IBT	92	4/12	0	4			
			2 = DBT	0	0/12	0	0			
			3 = TOU	0	0/12	0	0			
Industrial Tariff (IT)	Numerical	Categorial	0 = Linear rate	207	9/12	0	9	0.44	0.02	0.44
			1 = IBT	69	3/12	0	3			
			2 = DBT	0	0/12	0	0			
			3 = TOU	0	0/12	0	0			
2. Production										
Public utility (PU)	GWh	Continuous	-	276	520	0	2 877	842.73	76.97	839.35
IPP (IPP)	GWh	Continuous	-	276	77.56	0	686	165.56	12.47	165.11
3. Share of income in electricity by income quintile										
Q1 (Q1SIE)	Expenses ($/month)	Continuous	-	276	3.17	0	11	3.96	0	3.96
Q2 (Q2SIE)			-	276	3.33	0	13	4.32	0	4.32
Q3 (Q3SIE)			-	276	3.83	0	16	4.96	0	4,96
Q4 (Q4SIE)			-	276	4.58	0	22	6.37	0	6.37
Q5 (Q5SIE)			-	276	7.25	0	28	9.18	0	9.18
Control variables										
Population (POP)	Ln millions	Continuous	-	276	16.07	14.35	18.05	0.92	0.19	0.90
HDI (HDI)	Numerical	Continuous	-	276	0.37	0.19	0.52	0.08	0.04	0.07

Appendix C –Unit root tests

		Levin-Lin-Chu			**Harris-Tzavalis**		
Null hypothesis		• H0: at least one of the panels contains a unit root • H1: panels are stationary			• H0: at least one of the panels contains a unit root • H1: panels are stationary		
Decision rule		• If *P-value* > 0,10, we accept H0; there exists at least one unit root • If *P-value* < 0,10, we reject H0; panels are stationary			• If *P-value* > 0,10, we accept H0; there exists at least one unit root • If *P-value* < 0,10, we reject H0; panels are stationary		
		National access	**Urban access**	**Rural access**	**National access**	**Urban access**	**Rural access**
Group 1	**P-value**	**0.0000**	**0.0409**	**0.0000**	**0.0000**	**0.0015**	**0.0000**
	Unadjusted t-statistic	-16.8770	-5.3147	-13.4313	-0.0788	0.6852	-0.0671
	Adjusted t-statistic	-8.7799	-0.8683	-7.7274	-13.1072	-0.2494	-12.9103
Group 2	**P-value**	**0.0926**	**0.0982**	**0.0000**	**0.0000**	**0.0623**	**0.0000**
	Unadjusted t-statistic	-4.9814	-7.1138	-11.9308	-0.0673	0.6244	-0.0672
	Adjusted t-statistic	1.7827	-0.8683	-1.2918	-10.0030	-0.9849	-10.0017
Group 3	**P-value**	**0.0000**	**0.0351**	**0.0003**	**0.0000**	**0.0008**	**0.0000**
	Unadjusted t-statistic	-6.8e+02	-3.4249	-9.3391	-0.0674	0.6561	-0.0672
	Adjusted t-statistic	-6.8e+02	0.6282	-3.4307	-9.1321	-0.5221	-9.1302
Group 4	**P-value**	**0.0000**	**0.0986**	**0.0000**	**0.0000**	**0.0118**	**0.0000**
	Unadjusted t-statistic	-13.3842	-4.6270	-13.3593	-0.2333	0.7017	0.0785
	Adjusted t-statistic	-5.6067	1.2734	-6.9317	-16.4731	0.0296	-10.9707

For the independent variables of all country groups, we tested for the presence of unit roots using Livin-Lin-Chu tests, except in the case of SIE. For these variables, we used Harris–Tzavalis tests in order to control any size distortions of the quintiles. For all country groups, the tests detected no unit roots for the independent variables.

Appendix D: Hausman specification test: a choice between random- vs fixed-effects panel data models

<table>
<tr><td></td><td colspan="3">• μ_i are not correlated with the model regressors
H1: errors μ_i are correlated with the model regressors</td></tr>
<tr><td>Decision rule</td><td colspan="3">• If <i>Prob>chi2</i> > 0,05, we accept H0; random-effects model is applied;
• If <i>Prob>Chi2</i> < 0,05, we reject H0; fixed-effects model is applied</td></tr>
<tr><td></td><td>National access</td><td>Urban access</td><td>Rural access</td></tr>
<tr><td>Group 1</td><td>0.9996
(1.52)</td><td>0.9774
(2.62)</td><td>0.7648
(7.41)</td></tr>
<tr><td>Group 2</td><td>0.9998
(2.91)</td><td>0.4949
(7.39)</td><td>0.1968
(2.76)</td></tr>
<tr><td>Group 3</td><td>0.9999
(1.19)</td><td>0.7745
(2.60)</td><td>1.0000
(0.62)</td></tr>
<tr><td>Group 4</td><td>0.9531
(5.14)</td><td>0.1342
(8.43)</td><td>1.0000
(0.12)</td></tr>
</table>

Appendix E - Test for first-stage regression with "Number of blocks" as an instrument

E.1. In assessing the assess the robustness of the instrument "Number of blocks

H0: instrument is robust if F-statistic > Wald test at 5 %

Tests	Group 1	Group 2	Group 3	Group 4
F-statistic	401.831	209.35	302.85	581.205
Wald Test at 5%	16.38	16.38	16.38	16.38
Conclusion on the quality of instrument	Robust	Robust	Robust	Robust

E.2: Overidentification restriction test

To determine if Number of blocks (NB) is the only sufficient instrument to correct the endogeneity in price per blocks, we consider Lifeline Tariff (LT) not as a variable but as an another instrument

Sargan & Basmann test of overidentification : if p-value > 0.10, H0 is rejected : all instruments added are robust
if p-value < 0.10, H0 is accepted : at least on instrument is misspecified

Group	Goup 1		Goup 2		Goup 3		Goup 4	
Models	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
Intruments	**NB + LT**	**NB + LT**	**NB + LT**	**NB + LT**	**NB + LT**	**NB + LT**	**NB + LT**	**NB + LT**
- Sargan								
(Score) chi2(1)	31.648	38.9553	11.1693	3.55095	17.2319	9.3697	43.5348	55.7523
P-Value	0.0000	0.0000	0.0008	0.0595	0.0000	0.0022	0.0000	0.0000
- Basmann								
(Score) chi2(1)	38.427	50.3806	11.7783	3.5633	18.7025	9.7117	51.126	69.1058
P-value	0.0000	0.0000	0.0006	0.0591	0.0000	0.0018	0.0000	0.0000
Result	**H0 accepted**	**H0 accepted**	**H0 accepted**	**H0 accepted**	**H0 accepted**	**H0 accepted**	**H0 accepted**	**H0 accepted**

Decision : Mispecification : Number of Block is the only sufficient instrument

Y	Urban Access				Rural Access			
Groups	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
RT	**-27.122** *** (2.587)	**-30.882** *** (4.171)	**10.214** *** (1.717)	**-12.428** * (6.699)	**35.052** *** (3.291)	-4.332 (10.207)	**-16.677** *** (2.292)	**-3.810** *** (1.374)
NB	**25.993** *** (1.462)	**20.222** *** (2.608)	**-16.180** *** (1.043)	-0.767 (2.246)	**12.360** *** (3.215)	6.117 (6.532)	**-5.398** *** (1.369)	**-2.558** *** (0.461)
LT	**2.249** *** (0.134)	**2.053** *** (0.259)	0.113 (0.544)	**-1.923** *** (0.128)	**-0.656** *** (0.214)	**1.178** *** (0.184)	**1.573** *** (0.134)	-0.039 0.026
CF	**1.099** *** (0.283)	**-0.154** *** (0.056)	**0.192** *** (0.049)	0.033 (0.126)	-0.559 (0.592)	0.106 (0.084)	**0.054** ** (0.027)	-0.019 (0.026)
CF-1	-0.032 (0.329)	0.002 (0.029)	0.003 (0.031)	0.006 (0.105)	0.011 (0.661)	-0.00007 (0.023)	0.001 (0.023)	0.002 (0.022)
CF-2	-0.361 (0.238)	-	**0.072** *** (0.024)	0.084 (0.077)	-0.047 (0.458)	-0.020 (0.017)	**0.033** ** (0.017)	0.010 (0.016)
CT	**-32.304** *** (2.503)	**-12.997** *** (2.047)	1.384 (2.835)	**15.625** ** (6.367)	**-27.423** *** (4.444)	5.189 (2.690)	**3.670** ** (1.915)	-0.235 (1.306)
CT-1	0.005 (2.508)	-0.141 (1.585)	0.457 (1.454)	0.045 (8.686)	0.251 (3.905)	-0.123 0.738	0.642 (1.163)	-0.095 (1.781)
CT-2	-2.159 (1.839)	-1.194 (1.263)	**5.099** *** (1.369)	4.297 (6.336)	2.929 (2.670)	**-1.403** ** (0.559)	**4.990** *** (1.035)	-0.360 (1.299)
IT	**21.412** *** (1.500)	-0.877 (2.105)	-8.056 (1.690)	**-8.963** * (5.108)	**12.642** *** (3.412)	**-12.072** *** (2.129)	**-6.067** *** (1.898)	0.270 (1.047)
IT-1	-0.159 (1.470)	0.559 (2.321)	-0.251 (1.103)	-0.081 (6.236)	-0.117 (3.917)	0.233 (1.258)	-0.350 (0.713)	0.071 (1.279)
IT-2	0.859 (1.084)	**5.062** *** (1.829)	**-2.156** *** (0.855)	-1.621 (4.550)	-0.061 (2.584)	**1.779** * (0.936)	**-2.391** *** 0.603	0.244 (0.933)
PU	**-0.003** *** (0.0003)	**-0.004** *** (0.001)	**0.015** *** (0.002)	**-0.004** * (0.002)	**-0.005** *** (0.001)	-0.002 (0.001)	**0.012** *** (0.0008)	**0.001** ** (0.0005)
IPP	**0.017** *** (0.004)	**-0.003** ** (0.001)	**0.017** *** (0.004)	**-0.089** *** (0.006)	**0.087** *** (0.019)	**0.011** *** (0.003)	**-0.032** *** (0.008)	**-0.015** *** (0.001)
Q1SIE	17.503 (27.349)	-4.789 (26.103)	**-162.402** *** (12.164)	-4.268 (4.072)	**33.782** *** (2.566)	**8.012** *** (1.736)	**-30.730** *** (3.177)	0.769 (0.783)
Q1SIE-1	-0.015 (0.341)	0.065 (0.858)	0.157 (1.919)	0.035 (1.339)	0.068 (0.397)	-0.019 (0.346)	0.006 0.783	-0.009 0.262
Q1SIE-2	-0.170 (0.247)	0.715 (0.621)	**3.168** *** (1.356)	-0.174 (0.966)	**-57.739** *** (3.286)	-0.212 (0.250)	-0.008 (0.534)	-0.160 (0.189)
Q2SIE	-26.699 (36.195)	-15.599 (16.912)	**355.204** *** (27.947)	**21.390** *** (5.006)	**-57.739** *** (3.286)	-7.059 (0.971)	**59.475** *** (7.742)	**-1.611** * (0.962)
Q3SIE	15.841 (13.497)	17.091 (11.829)	**-308.817** *** 25.295	**-11.921** *** (1.165)	**3.286** *** (1.012)	0.516 (0.699)	**-46.319** *** (7.145)	0.199 (0.224)
Q4SIE	-0.731 (3.451)	-2.875 (3.557)	**198.416** *** (16.157)	**-6.875** *** (1.266)	**-1.740** *** (0.320)	-	**31.787** *** (4.297)	**0.478** ** (0.243)
Q5SIE	-2.201 (7.613)	-	**-83.422** *** (6.626)	**3.193** *** 0.3355697	**-7.106** *** (0.761)	-	**-14.655** *** (1.675)	-0.096 (0.064)
POP	**1.19e-06** *** (2.43e-07)	**3.86e-07** *** (5.68e-08)	**1.12e-06** *** (1.64e-07)	**6.77e-07** *** 1.13e-07	-4.81e-08 (5.50e-07)	**1.94e-07** *** (4.46e-08)	**1.59e-06** *** (2.50e-07)	2.99e-07 (2.31e-08)
HDI	**-7.953** ** (3.972)	**8.005** *** (2.963)	**21.756** *** (4.142)	-0.911 (5.216)	2.578 (4.271)	1.024 (1.674)	**-10.433** *** (4.097)	1.905 (1.070)
Constant	**60.537** *** (2.614)	**48.831** *** (3.167)	**32.655** *** (4.721)	**60.111** *** (3.705)	2.578 (4.271)	**-11.161** * (6.676)	**-7.783** *** (2.838)	4.397 *** (0.760)
Obs (N=782)	161	161	184	276	161	161	184	276
R-squared	0.8398	0.9745	0.8960	0.7872	0.3582	0.7853	0.6942	0.7702

Appendix F. Results obtained through the GMM estimator (Standard deviation with heteroscedasticity errors corrected
significance level * p ≤ 0.10, ** p ≤ 0.05, *** p ≤ 0.01)

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[i] There are 48 countries in sub-Saharan Africa; we have eliminated 12 from our sample due to lack of information and 3 small countries with abnormal values (Cape Verde, São Tomé and Principé and the Maldives).

[ii] In a block tariff, Increasing-Block-Tariffs (IBT) are intended to cross-subsidize low-consumption households, which may lack the ability to pay, and to discourage high consumption. On the contrary, Decreasing Block Tariffs (DBT) support large consumers. SSA countries mainly use IBT in residential tariffs.

[iii] In SSA, the rates charged are twice as high as those in Latin America and East Asia and four times as high as those in South Asia (Heuraux, 2009).

[iv] For the African power sector, the average total production cost is much lower than the incremental production cost because of the persistent dependence on fossil fuel (Deloitte, 2017), an insufficient level of technological competency (IAE, 2019: 63 for the backup cost), a frequently isolated set of production assets and a still too tight electricity market. This means that residential rates do not allow companies to recoup their initial capital investment costs. Moreover, the average revenue collected by power companies is still lower than the average tariff. The quasi-fiscal deficit (the gap between the revenue actually collected and that which power companies would collected if they charged a tariff based on real production costs) and hidden costs (insufficient revenue collection, system losses and overstaffing) mean implicit financial losses in the sector. This amount is substantial. At the level of residential rates, it represents 1.8-4% of per capita GDP (Huenteler & al., 2017).

[v] Uganda, Madagascar, Kenya, Nigeria, Tanzania, Chad, Côte d'Ivoire, South Africa and Zimbabwe.

[vi] While it is difficult to evaluate the non-payment rate, it is estimated to reach an average of 40%: 60% for households in the first income quintile and 20% in the last quintile (Del Granado et al. 2012)

[vii] In SSA, energy consumption subsidies point to a context marked by high household poverty. The average monthly household income is $180, stretching from $60 in the poorest households to $340 for the richest (Eberhard et al., 2011).

[viii] Some countries classify industrial consumers as high-voltage using a scale between 11-33 kV (Nigeria and Lesotho) while others have only medium- and low-voltage consumers. The only high-voltage line in the electricity pricing is a 132-kV line connecting Ethiopia, Kenya and South Africa.

[ix] In rare cases, electrification is financed through mechanisms based on cross-subsidies between urban and rural residents (e.g., Eskom in South Africa).

[x] Cameroon, Democratic Republic of the Congo, Ghana, Mozambique and Zambia.

[xi] In Cameroon, Democratic Republic of the Congo and Zambia, the price set for grid services is less than a tenth of the real cost of self-supply through a classic 5 MW diesel generator. In these countries, the rates are set well below the long-term marginal cost (Banerjee et al., 2015).

[xii] We were interested in controlling for institutional quality. Unfortunately, both Polity2 and the Ibrahim Index that we used lead to the same dead end: in their current state of construction, these indices introduce multi-collinearity with other explanatory variables without our being able to identify which ones and thus correct for them. We have therefore chosen not to control the model for the quality of institutions.

[xiii] The Africa Country Infrastructure Diagnostic Database from the African Development Bank and the World Bank.

[xiv] Initially, this variable was prices of consumption blocks for. As explained below, due to endogeneity, this became an instrumental variable.

[xv] Most approaches to learning from incomplete data are based on the assumption that unobserved values are missing at random. Indeed, missing at random (MAR) is always a safer assumption than missing completely at random (MCAR), because any analysis that is valid under the assumption that the data is missing completely at random will also be valid under the assumption that the data is missing at random, but the opposite is not true.