Urbanisation and energy consumption in Sub-Saharan Africa

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DECLARATION

I, Muez Ali Abdelgadir Ali, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

ABSTRACT

Sub-Saharan Africa has the lowest electrification rate and highest urbanisation and population growth rates globally. The increase in population and its move towards urban areas is expected to put pressure on existing energy infrastructures and government budgets, introducing uncertainty in the path that future resource consumption might take. Research on the effects of urbanisation on energy use in Sub-Saharan Africa is scarce, with few studies only looking at this issue in two countries. Furthermore, the institutional structure and quality of governance of Sub-Saharan African governments and the policies they implement to deliver energy to urban and rural residents in African cities are seldom studied.

This research explores the relationship between urbanisation and energy consumption in Sub-Saharan Africa in three ways, starting from an aggregate level and zooming in to the household level. First, by estimating the effect of urbanisation on energy consumption while controlling for demographic, economic and geographic factors using econometric analysis of country-level data. Second, by studying the impact of the quality of governance across countries on electricity access in urban areas. And third, focusing on one country, by investigating how access to electricity for rural and urban poor households is influenced by government policy using data on household electricity consumption in Rwanda.

This thesis quantifies the effect of urbanisation on total energy consumption and electricity consumption in Sub-Saharan Africa using country-level data on 44 Sub-Saharan African countries. The results of the analysis show that urbanisation has a positive and significant effect on total energy consumption but no effect on electricity consumption. Then, using a multimethod approach involving econometric analysis of country-level and project-level data and country case studies, investigates the relationship between governance and electricity access in urban and rural areas. The findings suggest a negative relationship between governance and urban electrification, where urban electricity access is prioritised with more autocratic governments with low quality of governance and rural electrification is prioritised with more democratic governments with higher quality of governance. Ghana, Gambia, Togo and Benin are presented as examples where these dynamics manifest. Finally, using household level data and exploiting Rwanda's post-genocide settlement policies, this thesis explores the impact of government policy on the likelihood of households having access to electricity. The results show that households living in government planned settlements are more likely to have access to electricity than their counterparts in isolated or spontaneous settlements.

The original contribution of this research is in quantifying the effect of urbanisation on energy consumption in Sub-Saharan Africa, providing descriptive and empirical evidence of the relationship between governance and urban electrification, and quantifying the impact of policy on access to electricity for low-income households.

IMPACT STATEMENT

This thesis investigates the effect of urbanisation and energy consumption in Sub-Saharan Africa, the relationship of governance on electricity access in rural and urban areas, and the impact of government on policy on electricity access for low-income households. The findings have a potential impact for energy policy in the African continent.

This thesis contributes to three strands of literature. It contributes to the large literature on the effect of an increasing urban population on different types of energy in developed and developing countries. Furthermore, this thesis contributes to the growing literature on governance and public service provision in developing countries. Finally, this thesis adds to existing literature on government policy for expanding energy access for low-income households in developing countries.

This thesis contributes the first investigation of the relationship between urbanisation and energy consumption for Sub-Saharan African countries and investigates a new research question on the relationship between governance and urban electricity using a novel project-level dataset. This thesis also uses a new household energy survey to examine the effect of government policy on the likelihood of electricity access for low-income households.

For policymakers, the findings of this research can inform how governments make decisions on infrastructure expansion. First, the findings show that energy infrastructure must keep up with the needs of an increasing urban population. Second, given the budget limitations of governments in Sub-Saharan Africa and the importance of the industrial sector to economies across the continent, there may be a case for prioritising urban electrification. Finally, the results point to the importance of targeted infrastructure and expansion in line with other policies, such as housing and settlement policies and broader development policies.

The findings of this research have been shared with a broad audience within academia. Some of the preliminary results of this research have been published in a special issue of The Electricity Journal. I have presented the findings from this thesis at two academic conferences, the 2021 Energy Policy Conference and the 2021 RGS-IBG Annual International Conference. I have also presented some of the preliminary results at two seminars, the ISR Lunchtime Seminar Series at UCL and LSE's International Development Seminar Series.

The knowledge I have acquired throughout this PhD have been invaluable for my development as a researcher. I have used the skills I've acquired in data cleaning, data analysis and sampling to design a large household survey for the Sudanese government as a Research Associate at the Ministry of Finance and Economic Planning in Sudan. In this same role, I used the knowledge I've acquired on energy systems and energy use in developing countries to design a fossil fuel subsidy reform strategy for Sudan. As a consultant, I have applied research skills I acquired in reviewing literature in the duration of the PhD to recent assignments with the World Bank and KPMG. Finally, I used the broad set of teaching skills I acquired as a post-graduate teaching assistant during the PhD to design and deliver short courses on game theory, energy systems and quantitative research to Sudanese undergraduate students.

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DEDICATION

I dedicate this thesis to my wife, for all the sacrifices she made, to my mother, Huda Abdelsattar, who sacrificed her own career as a researcher to take care of me and my siblings, and to my late father, Ali Abdelgadir Ali, who passed away on September 16th, 2022. He was not a pious man, but he once told me, “What use is your PhD? The Righteous Caliphs of the Prophet Mohammed (who are guaranteed a place in heaven) did not even go through primary education.” He was an economics professor.

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1 Chapter 1: Introduction

1.1 Context and rationale for the study

1.1.1 Energy in developing countries

Energy consumption is an integral part of economic growth. Most industrialised countries today have consumed sizeable amounts of energy during the process of industrialisation. This, however, has come at a large cost to the environment. Per capita consumption of energy for most industrialised countries has plateaued and per capita emissions have been declining for the last two decades. This is a consequence of the realisation of the negative impacts of energy use on the environment, the development of more efficient technologies and adoption of new environmental protection regulations. For developing countries[1], the story is different. In the past three to four decades, the emerging economies of Asia, most notable China and India, have started a similar industrialisation process as that of already industrialised countries. As a result, today, China is the largest emitter of greenhouse gases. India is fourth, after the United States and the European Union. Both countries must now abide by global agreements that put a cap on emissions and require countries meet specific emission targets (IPCC, 2022). Unless a climate compatible growth trajectory is followed, this will put some limitations on their growth ambitions. However, not all developing countries have the same problem. While today emissions in the US are 14.7 metric tons of CO2 per capita (down from 20.5 in 2000) and 7.6 metric tons of CO2 per capita in China (up from 2.7 in 2000), in the Least Developed Countries (LDCs), most of

[1] Developing countries is one the broad categories used by the United Nations to group countries. The three broad categories are: developed countries, countries in transition and developing countries. The developing countries category includes low-income and lower middle-income countries. The countries studied in this thesis are in Sub-Saharan Africa, which includes low-income, lower middle-income and upper middle-income countries. Throughout the thesis, they are collectively referred to as Sub-Saharan African countries as an implicit sub-category of developing countries.

which are in Sub-Saharan Africa, per capita emissions are 0.4 metric tons of CO2 per capita (World Bank, 2020a).

Limiting the emissions of developing countries is likely to have an impact on their economic development. The relationship between energy use and economic development depends on several factors. An insufficient supply of energy, as is the case in most Sub-Saharan African countries, puts constraints on economic growth (Stern, 2011). In Pakistan, for example, a shortage of electricity and petroleum consumption is found to have a potential contractionary effect on economic growth (Siddiqui, 2004). In a group of Asian economies, including Pakistan, energy is found to have a significant positive impact on economic growth (Azam, 2020). In some developing countries, such as Brazil, where self-sufficiency and energy independence are realistic goals, there is a positive causal effect from low-carbon renewable energy to economic growth (Pao and Fu, 2013). Other options of achieving low-carbon growth include decoupling economic growth from fuel consumption through energy efficiency measures, such as in China, or through the adoption of more advanced technologies, as is being attempted in India (Wang, Jiang and Zhan, 2019).

Furthermore, the weak link between electricity consumption and economic growth in regions such as Sub-Saharan Africa and the Caribbean have led some to argue that electricity conservation policies would not hurt growth prospects (Sharma, 2010). But, for the same two regions, fossil fuel energy consumption has a significant impact on growth. Knowing that hydropower is the main source of electricity for many Sub-Saharan African countries (World Bank, 2020a), electricity conservation policies in this context will likely have a subdued effect on carbon emission. Moreover, there is no consensus on the relationship between renewable energy consumption and economic growth in Sub-Saharan Africa as a growing strand of literature on the topic shows mixed results (Alege, Jolaade and Adu (2018) find a bidirectional relationship between renewable energy and economic growth, while Qudrat-Ullah and Nevo (2022) find no relationship).

A lot of the recent literature on developing countries deals with energy from a climate change perspective. For example, Collett and Hirmer (2021) call for better data to help achieve an electrified public transit system for Sub-Saharan Africa to tackle issues of fuel scarcity, but, mainly, because it’s potentially better for the environment. And several studies emphasise the need for Sub-Saharan African countries to accelerate renewable energy adoption (see, for example, Ulsrud et al. (2015); Barasa et al. (2018); Oyewo et al. (2019); Mukelabai, Wijayantha and Blanchard (2022)). The lack of affordable finance, however, is making it difficult for developing countries to invest in mitigation, adaptation, and recovery measures (UN, 2022).

Furthermore, looking at energy in developing countries from a climate change perspective has several limitations. First, developing countries are the most vulnerable to the negative impacts of climate change (Sarkodie, Ahmed and Owusu, 2022). Poor infrastructure in the face of an increasing urban population is expected to put more pressure on already limited resources (UNDESA, 2019). Lack of sufficient government capacity and weak and inadequate social safety nets make dealing with extreme climatic events difficult (Costella *et al.*, 2021). Governments in developing countries don’t have the capacity to deal with the impending climate crises, nor do existing safety nets cover the regions that are most impacted (World Bank, 2013a). The implications are significant. Climate-induced cross-border migration, and within country migration (WMO, 2021), will put even more pressure on governments in the region and lay the foundations for potential political instability (Brookings, 2022). This means, poor countries lose out twice. Poor countries did not benefit from the economic growth and industrialisation of the twentieth century powered by fossil fuels. And precisely because they didn’t benefit, today they are the least prepared to deal with environmental consequences of this growth.

Within this context, energy use in developing countries, as opposed to being restricted by climate considerations, could be viewed as an enabler of growth and resilience. Both of which require strong physical and institutional infrastructure. The increasing severity and frequency of extreme climate events will force large number of people to move to areas that are more habitable (Viviane *et al.*, 2021). These trends are expected to have local and regional impacts (WMO, 2021). Urban areas in developing countries, where service provision and infrastructure are relatively better, are at risk of a large influx of people (UNDESA, 2022). Historically, governments have dealt with internal migration and displacement resulting from droughts, floods, or war by housing people in camps or areas with temporary housing (Avogo and Agadjanian, 2010; Lilleor and Van den Broeck, 2011; Kuhn, 2015). In these areas, the availability and consistency of infrastructure and public services depends on political, economic, and social factors (Black *et al.*, 2011). But as migratory trends become less transitory, more permanent solutions are needed to deal with the inevitable increase in demand for housing and services, such as health, transport, and energy.

1.1.2 Energy consumption in Sub-Saharan Africa

In Sub-Saharan Africa, looking at energy from a climate change lens is even more problematic. Of the 46 LDCs mentioned earlier, 32 are in Sub-Saharan Africa. As a group, LDCs have performed poorly in the last decade: significant decline in economic growth between 2007 and 2017, declining share of global exports, stagnant industry share of GDP and lower inflows of foreign direct investment (UNCTAD, 2018). Not surprisingly, the impact of COVID-19 has been especially harsh on LDCs. Despite having relatively low incidence of the virus, LDCs have felt the impact of the pandemic on the global economy and supply chains. Most of the countries experienced significant food shortages, rising income and educational inequalities intensified by technological gaps and severe budget deficits (UNCDP, 2021). The energy sector was hit just as hard. Despite the recent progress in electrification across the continent, the COVID-19 pandemic hampered the trajectory of the previous 10 years for Sub-Saharan Africa, where 568 million people still don't have access to electricity (IEA IRENA UNSD World Bank WHO, 2022). Among other things, this further cemented the divide in urban-rural electrification. The largest populations without access to electricity are in some of the largest economies in the continent. In Nigeria (92 million people without access to electricity), Ethiopia (56 million) and the Democratic Republic of Congo (72 million), electrification efforts have not been able to keep up with population growth (ibid.).

The energy mix of Sub-Saharan African countries varies significantly from more developed regions. Biomass accounts for almost 50% of total primary energy supply, down from 70% in 1970 (IEA, 2022), mostly used in the residential sector. Fossil fuels account for around 30%, mostly in the form oil and natural gas (ibid).

Coal is the main source of electricity production in the sub-continent and is mostly used in South Africa. Total final energy consumption is dominated by household use of biomass. The transport and industrial sectors account for just under a fifth of total final consumption. The dominance of the residential sector is mostly due to the use of traditional biomass, which is expected to decrease as more households get electrified. Current household electricity consumption is driven by demand for refrigeration, space heating and cooling (IEA, 2022). Electricity demand is expected to double by 2030 (IEA, 2022). An increase in the adoption of efficient cooking technologies is also expected to reduce household consumption of traditional biomass. Transport energy demand is fossil fuel dominated and almost half of the end-use is in the transport of goods. Understandable, passenger cars make up only a quarter of end-use demand in the transport sector. Despite recent optimism, it is unlikely that electric vehicles will penetrate the market soon, mainly due to the low generation capacity in most countries. The number of passenger cars is expected to increase significantly in the next decade (ibid.), which means an increased demand for fossil fuels.

Fossil fuel demand will also increase because of electrification expansion. Outside of South Africa, hydroelectricity dominates electricity production, followed by oil and natural gas. Given the geographical limitations of hydroelectricity adoption, it's likely that most of the increase in demand for electricity will be supplied by fossil fuels. But the IEA predicts, by 2030, installed capacity of solar PV will equal that of natural gas. In 2020, total electricity access in Sub-Saharan Africa was 48%, a significant increase from 25% in 2000. In urban areas, electricity access reached 78%, but rural areas remain largely unelectrified with only 28% of rural populations having access to electricity (World Bank, 2022). This is particularly difficult for the continent's economic growth ambitions. The benefits of having access to electricity are well established (see, for example, Srivastava et al. (2012); Coelho and Goldemberg (2013); Grimm, Hartwig and Lay (2013); Sievert and Steinbuks (2020)). And many have argued that electricity access is a major hurdle for poverty alleviation efforts in developing countries, including Sub-Saharan African (see, for example, Pereira, Freitas and da Silva (2010); Sovacool (2012); Parikh et al. (2015); Lenz et al. (2017)).

The IEA predicts that the expansion of electric vehicles in Sub-Saharan Africa in the next decade will be limited to two- and three-wheeler vehicles and buses in public transport networks (IEA, 2022), and most of the growth in small electric vehicles will be in urban areas. This is primarily due to the limited capacity and penetration of electricity grids and the practicality of charging smaller electric vehicles in off-grid solar-PV charging stations. Despite the higher price of electric two- and three-wheelers relative to their petrol- and diesel-powered counterparts, they are cheaper to run in the long-run (Rokadiya, Bandivadekar and Isenstadt, 2021).

Another source of demand growth for electricity in the future is the switch to electric cooking in Sub-Saharan African countries. Electric cooking is considered a cleaner alternative to existing cooking practices, which are dominated by traditional fuels burnt in traditional cookstoves. The push for electric cooking is seen as beneficial for both consumers and providers of electricity. For example, in Kenya, electric cooking is considered as “a way to stimulate demand, and revenue, to accelerate cost recovery for the energy distributor” (IEA, 2022, p. 119). The same report, however, emphasises that most households that use polluting fuels have access to electricity and pay relatively low tariffs. Which, supposedly, should make the switch to electric cooking easier – but this doesn’t satisfy the revenue guarantee for utilities because of the low tariffs paid by households.

The IEA’s Sustainable Africa Scenario forecasts that by 2030 most of the electricity consumed for productive uses will be in the industrial and services sector, with oil products (mostly diesel) still dominant in agriculture (IEA, 2022). The current expansion of solar-PV in agriculture has so far been limited to small-holder farmers, with large agricultural projects preferring grid electricity or diesel generation. This is understandable given the limited grid access in agricultural areas, the capital costs and institutional barriers involved in grid extension for small-holder farmers, and the existing electricity subsidies for agricultural projects in most Sub-Saharan African countries. Therefore, future demand for electricity, at least in the next decade, might follow previous trends and stay confined to the industrial and residential sectors in urban areas. Having said that, governments in Sub-Saharan Africa will have to be creative in how to satisfy this demand. For example, despite the IEA's prediction of slow growth in electric vehicle adoption, demand for electric charging for smaller vehicles can be met with off-grid charging stations that are not limited by the same spatial and capital constraints as grid expansion.

The contribution of the informal sector to total economic output in both rural and urban areas is often ignored (Westphal *et al.*, 2017). This is particularly problematic regarding energy provision. First, governments are generally reluctant to provide services to informal settlements because of planning restrictions (Rozita Singh *et al.*, 2015) and utilities are usually unwilling to serve areas where there is no guarantee of long-term demand (Baruah, 2015). Despite this, households in informal settlements and businesses operating in the informal sector access electricity through wiretapping and consume traditional fuels for cooking. Given the size of the informal economy in Sub-Saharan Africa, where informal employment accounts for 89% of total employment (ILO, 2018), and its demographic composition – more than 90% between ages 15 and 24 (UNDESA, 2022) – demand for energy in the informal sector will continue to grow in the future. However, data on the informal sector is scarce, particularly on the energy demand dynamics of the urban informal economy. So, while this thesis acknowledges the importance of the informal sector in shaping the energy landscape in Sub-Saharan African countries, a macro-level analysis is conducted due to lack of information on the sector.

1.1.3 Urbanisation, institutions, and electricity access

Urbanisation is the movement of people from rural to urban areas. People move for many reasons. Some move seeking better economic opportunities, others migrate to avoid conflict, famine, or drought. The increase in the frequency of extreme climatic events due to climate change will increase migratory behaviour, both locally and regionally (Cobbinah, Erdiaw-kwasie and Amoateng, 2015). Sub-Saharan African countries are the least urbanised in the world and are expected to experience large increases in urban populations in the coming decades (World Bank, 2020a). Economic conditions play a crucial role in migration. As incomes rise in urban areas relative to rural areas due to rapid economic growth, rural populations are enticed to move to urban centres (Black *et al.*, 2011).

Due to recent economic development, improvements in infrastructure and transportation networks make migration cheaper and safer (Awumbila, 2017). Another major driver of internal migration is conflict. Political stability can attract immigrants or suppress internal migrants by supporting local development. Who migrates is also an important factor in determine trends in urbanisation. Demographic effects on migration are not the direct consequence of the demographic makeup per se but are typically driven by the economic and social characteristics of the sourcing and receiving areas. Environmental effects on migration act through climate variability, through the constant fluctuations in climate-related weather events, such as rainfall or droughts (Awumbila, 2017). The factors that determine urbanisation will ultimately influence service provision in urban areas. The urbanisation process demands the development of critical infrastructure to accommodate the needs of an increasingly urban population. Urbanisation will increase demand for energy, water, transport, education, and security.

How these services are used and whether they are provided also depends on specific economic, institutional, and demographic factors. The institutional structure can determine if rural residents are willing to leave for urban areas at all and who can access these services in urban areas. Considering these factors, to plan for the inevitable increase in urban populations in Sub-Saharan Africa, we must understand how urbanisation affects energy consumption. In Sub-Saharan Africa, for which evidence is scarce, an increase in the urban population will put the continent's ailing infrastructure under significant pressure. Also, it is not immediately obvious what the impact of urbanisation would be on total energy consumption because of the incidence of poverty and the prevalence of biomass as a primary energy source for most households. It is also not obvious how urbanisation will affect electricity demand because of low electrification rates across the continent.

Furthermore, institutions play a crucial role in the delivery of public services (Lake and Baum, 2001; Adserà, Boix and Payne, 2003; Brown, 2006; Harding and Stasavage, 2014). A significant amount of evidence suggests a positive relationship between institutional quality and public service provision. Moreover, where electricity is extended to has been the subject of a growing literature on the impacts of institutions on electricity use (Onyeji, Bazilian and Nussbaumer, 2012). Electricity can be used as a political tool and electricity provision can be manipulated to influence the outcomes of elections. So, the extension of grid electricity does not only depend on institutional quality but on the structure of government. Politicians looking to get voted back into office can extend access to key constituencies, and an autocrat looking to consolidate power can prioritise urban areas where the biggest political threat exists. This has an implication on whether rural or urban areas are electrified, and, more crucially, the impact for low-income households is not clear, especially since they tend to live in areas with no access to the grid, even in urban centres.

Energy access for low-income households in both rural and urban areas is hindered by several factors: no strategic and long-term planning; structure of settlements limiting access to modern fuels; high upfront costs of clean technologies; limited institutional support and engagement; ineffective subsidies. There are plenty of factors that influence a household’s use of electricity: demographic characteristics and proximity to markets and urban centres (Rahut *et al.*, 2017), energy policy targeted at low-income areas (Dhingra *et al.*, 2008), and city-level policies (Gulyani, Bassett and Talukdar, 2014). One significant demand-side barrier to modern energy access in urban slums is affordability. Poor households, on average, pay a larger portion of their income for low-quality energy services. As a result, some households that reside in areas where electricity is available, resort to extension cords and other informal means. And having a higher income does not necessarily protect households from being energy poor (Shahidur R. Khandker, Barnes and Samad, 2012). This highlights the importance of energy policy in ensuring access to energy services for the most vulnerable households. There are examples of government policies that had a positive impact on energy access for low-income households: the LPG distribution and the “Light for all” grid extension programmes in Brazil (Coelho and Goldemberg, 2013), and an electrification programme in parallel with house registration policies in Thailand (Shrestha *et al.*, 2008). There are also examples of badly designed programmes: Dhaka’s slum electrification programme failed to afford a meter for each household and relied on local community leaders to distribute electricity (Lipu, Jamal and Miah, 2013). The importance of government policy cannot be overstated and is sure to play a significant role in energy provision in the coming decades for Sub-Saharan Africa.

1.2 Research questions

With the increase in the urban population in Sub-Saharan Africa, there is a need for governments to plan for how to meet the inevitable increase in demand in energy. The important role that institutions play in public service provision and delivery requires a deeper understanding of the different incentives that governments face in providing electricity to the population. Finally, it is also vital to understand the impact of government policies at the household level and how they affect low-income households' ability to access electricity. To that end, this thesis uses a mixed methods approach to answer the following research questions:

- Research question 1: what is the effect of urbanisation on energy and electricity consumption in Sub-Saharan Africa?
- Research question 2: what is the relationship between governance and urban electricity access?
- Research question 3: what is the effect of government policy on access to electricity for poor households?

1.3 Original contributions

This thesis contributes to three main strands of literature. First, it adds to the large and growing literature on the relationship between urbanisation and energy consumption, by contributing the first continent-wide study on Sub-Saharan Africa. The literature on urbanisation and energy consumption has covered most regions in the world, but there are no studies that specifically investigate this relationship for Sub-Saharan African countries. It is important to look at Sub-Saharan African countries in isolation of other regions in the world because of the relative similarities in pre- and post-colonial histories, infrastructure development, demographic, and economic structures. This is not to say that there is no cross-country heterogeneity, but there are more similarities within the continent than between Sub-Saharan African countries and countries from other regions of the world, such as South America and Southeast Asia. For example, a lot of the ethnic groups within the continent are spread across official borders: members of the Tutsi and Hutu ethnic groups live in both Rwanda and Burundi, and the Fur tribe are mainly located in Western Sudan but many reside in Chad. This is true across the continent. Several countries also share key infrastructure, such as the West Africa Power Pool that connects 14 countries in West Africa and Southern African Power Pool that connects the countries in the Southern African Development Community. This thesis fills the gap in the literature identified in Section 2.5 by looking at the effect of urbanisation on both energy consumption and electricity consumption.

Second, this thesis contributes to the literature on the relationship between institutional quality and public service provision, and to the growing literature on the relationship between governance and electrification (see, for example, Brown and Mobarak (2009); Onyeji, Bazilian and Nussbaumer (2012); Ahlborg et al. (2015); Trotter (2016)). And within this literature, the relationship between governance and rural electrification has been studied in considerable detail. While there are studies on the provision of electricity to slums in developing countries (Aklin *et al.*, 2015), there are no studies that consider the relationship between institutions and urban electricity access, and there are no studies that look specifically at Sub-Saharan African countries. To that end, this thesis argues, and provides empirical evidence, that a negative relationship exists between governance and urban electricity access: less democratic governments priorities urban electrification because the urban population provides the biggest political threat. Moreover, using project-level data, this thesis also contributes empirical evidence of the relationship between quality of governance and electricity provision to rural and urban areas. Finally, this thesis contributes qualitative evidence of the relationship between governance and urban electricity access using four country case studies: Togo, Benin, Gambia and Ghana.

Third, this thesis adds to the literature on the effects of government policy on energy access for low-income households (see, for example, Coelho and

Goldemberg (2013); Patterson, Eberhard and Suarez (2002); Shrestha et al. (2008)). This thesis addresses a gap in the literature, highlighted in Section 2.5, of quantitative evidence, using household-level data, of the effect of government policy on the likelihood of households having access to electricity. Using the richness of a new dataset from a household energy consumption survey conducted in Rwanda, empirical evidence is provided on the likelihood of households living in different habitats of having access to electricity from the grid. The empirical estimation provides an estimate of how more or less likely households living in government planned settlements in Rwanda, Umudugudu, are of having access to electricity than their counterparts in isolated rural areas, clustered/unplanned rural areas, and unplanned urban areas. Thus, the original contribution is two-fold: quantitative evidence of the impact of the Rwandan government's housing policy on electricity access for households; and the use of a new household-level dataset on energy consumption in Rwanda.

1.4 Thesis structure

This thesis consists of six chapters. Chapter 1 introduces the topic of the thesis and outlines the research questions. Chapter 2 provides a review of wider literature on the relationship between urbanisation and energy consumption, the role of institutions in public service provision, and electricity access for low-income households in rural and urban areas. Chapter 3 presents the data and methodology used to answer research question 1 and provides the results of the analysis and discusses their implications. Chapter 4 presents the initial exploratory analysis conducted to answer research question 2, then presents the data, methodology and results of the empirical estimation, and presents 4 country case studies. Chapter 5 presents the context, data and methodology for answering research question 3 and provides the results of the analysis and discusses their implications. Finally, 6 summarises the main findings of the thesis and their wider implications and provides a self-reflective assessment of the limitations of the research and provides some thoughts on future research.

2 Chapter 2: Literature review

Section 1.1 sets the context on energy consumption and access in Sub-Saharan Africa. This chapter presents a review of the literature on urbanisation and energy consumption, institutions and public service provision, and electricity access for low-income households and the role of government policy.

2.1 Urbanisation in developing countries

The urbanisation process in Sub-Saharan Africa can be traced back to the colonial era. Colonial governments established administrative centres in urban areas to manage resource extraction in rural areas (Portes, 1976). This system – urban administered, rural production – persisted into the post-colonial era, where large capital and coastal cities managed and exported raw materials produced in rural areas. During this time, the increase in foreign trade and influx of foreign investment changed the structure of the labour market in most countries (Walton, 1977). This manifested into higher wages, higher income and higher consumption in urban areas and significant differences in labour productivity between urban and rural areas. The concentration of capital in urban centres led to the development of commercialised agricultural production – partly in response to pressure from foreign investors – which replaced rural farmers, many of whom eventually migrated to urban areas (Bradshaw, 1985).

These dynamics created the conditions for what Lipton (1977) termed 'urban bias.' The disparities in political and financial power between the centre and the periphery incentivised governments to prioritise urban areas over rural areas. In the post-colonial era, urban-bias led to disproportionate increases in non-agriculture investment and urban-centred benefit allocation (Bradshaw, 1985). For example, governments implemented several policies to keep food prices low in urban areas fearing discontent from the urban population (Bates, 2014). Low food prices in urban areas meant food was affordable for workers and it benefited employers by keeping wages low. First, this was achieved at the expense of farmers in rural areas who were forced to sell their produce at low prices. Second, governments consistently over-valued their local currencies to attract imports –

including food – which increased the supply of food in the domestic market and kept prices low (Bradshaw, 1985). Third, subsidies for agricultural inputs for large-scale agricultural projects were used to increase productivity in the sector. However, the subsidies were not made available to small-scale farmers, who could not compete (Bates, 2014), which led to more rural-urban migration. The impact of these policies persists to this day. In all Sub-Saharan Africa countries, service provision is better in urban areas than in rural areas. This is most evident in electricity access, where, on average, 78% of urban residents have access to electricity and only 28% of rural residents have access to electricity in the continent (World Bank, 2020a).

Today, Africa is the least urbanised continent in the world. This is expected to change by 2050 when the urban population in Africa is set to exceed that of Europe, North America and South America. This has consequences for both energy consumption and carbon dioxide emissions. Migration due to environmental, economic or political shocks has been chiefly confined to the continent as cross-border, rural to urban or inland rural to coastal urban migration, not as international migration to the West (Annez, Buckley and Kalarickal, 2010; Seto, 2011). As risks of conflict and economic stagnation increase because of climate change, Sub-Saharan African cities will bear the brunt of the subsequent migration. This is further exacerbated by the lack of adequate urban management, infrastructure and service provision in Sub-Saharan African cities, partly due to the uncoupling of urbanisation and industrialisation in the continent (World Bank, 2009; Annez, Buckley and Kalarickal, 2010).

More importantly, it is predicted that most of the continent's future urban growth will occur in small and medium-sized cities (Awumbila, 2017). This is particularly ominous for urban service provision. Because of colonial governments' "urban-bias" policies – policies prioritising the well-being of colonial civil servants and other Europeans – most of Sub-Saharan Africa's infrastructure today is concentrated in the large million-plus cities (Njoh, 2003). Therefore, most Sub-Saharan African cities are not ready for the coming wave of unplanned urbanisation. More worryingly, the countries that are the least prepared will experience the fastest rate of urban population growth, namely the least urbanised, lowest-income countries.

2.1.1 Drivers of urbanisation

In developing countries, the internal movement of people from poorer to wealthier areas is a consequence of many factors. People tend to move from poorer to relatively more prosperous regions, but income alone cannot explain the process. The more prosperous areas are urban centres, where migrants expect to find better income opportunities, security, and better services. Urbanisation, therefore, can be a direct consequence of internal migration. How and why internal migration happens depends on many factors. The frequency, scale and path of migration are related to individual circumstances, such as income, race and religion, and broader economic, political, demographic, social and environmental influences (Black *et al.*, 2011).

Urbanisation has two different definitions. It refers to the movement of people from rural to urban areas and the number of people living in urban areas. The urban population will thus increase due to migration and the natural growth of the urban population (Parnell and Walawege, 2011). In the Sub-Saharan African context, the number of people living in urban areas will also increase due to the reclassification of certain settlements due to the expansion of cities (McGranahan *et al.*, 2009). The different underlying dynamics that drive urban population growth are important. For example, in the early 2010s only about 30% of population growth in Sub-Saharan African cities was due to rural to urban migration. Because of high fertility rates in the continent, the natural increase in the urban population is projected to be a more significant contributing factor to urbanisation than internal migration by 2050 (McGranahan *et al.*, 2009). This growth in the urban population will require critical infrastructure development to accommodate new urban residents. The natural increase in the urban population and reclassification of settlements don't feature a dramatic change in people's circumstances and, therefore, could have a muted effect on behaviour (McGranahan et al. (2009) argue that slums in urban centres house migrants as well as long-term residents, and that low-income migrants who make the economically rational decision to move to an urban area (UNFPA, 2007) are more "upwardly mobile" than their urban counterparts). Or equally, a reclassification of an area as urban can influence service provision, such as the likelihood of a grid connection.

Economic conditions play a crucial role in migration. More specifically, income gaps are perceived as the most significant economic driver of both internal and external migration (Stark and Bloom, 1985; Black *et al.*, 2011). As incomes rise in urban areas relative to rural areas due to rapid economic growth, rural populations are enticed to move to urban centres. There is also the view that it's not the difference between wages in rural and urban areas that drives urbanisation but the expected wages in urban areas and the probability of finding a job; in other words, a migrant calculates the future earnings given her wage expectation and the chance of employment and then decides whether to move or not (Lilleor and Van den Broeck, 2011). There is also the lure of urban lifestyles in large cities. Educated and skilled young migrants are attracted to the benefits provided by the co-location of firms and specific service providers (Seto, 2011). The clustering of firms in the industry and services sectors tends to lower costs of production, which induces investment, growth and better quality of life (Cobbinah, Erdiaw-kwasie and Amoateng, 2015).

Furthermore, the improvements in infrastructure and transportation networks tend to make migration cheaper and safer. The prevalence of education and increased access to information will improve people's ability and ambitions to migrate (Awumbila, 2017). Barring any conflict or political instability, most people migrate to urban areas to realise their aspirations of a better quality of life. Migration, however, cannot be explained by economic incentives alone.

One of the main drivers of internal migration is conflict. While civil war has the most significant impact on migration, incidents of genocide, riots and changes in government are all positively related to migration (Davenport, Moore and Poe, 2003). Conflict-related migration depends on several factors. The option to migrate depends on the ability to do so (Raleigh, 2011). People with higher incomes and more assets are more likely to migrate in the event of social, political or economic disruptions (Avogo and Agadjanian, 2010; Lilleor and Van den Broeck, 2011). Essentially, people moving to urban areas, for whatever reason, are not necessarily the poorest.

On the other hand, political stability and government policies on relocation can affect migration. Political stability can attract immigrants or suppress internal migrants by supporting local development. Government policies, such as the Special Economic Zones in China, can encourage people to move to urban areas (Black *et al.*, 2011). Other factors, such as land ownership and regional development plans, can also affect migration. For example, in Vietnam, farmers who don't own the land they work on don't invest in preserving the land's productivity, which ultimately reduces the crop yield and increases the prospect of migration (Seto, 2011). Therefore, institutional and political factors play a crucial role in determining the level of migration within a country's borders, whether through war and instability or urban-centric government policies. But the ability or likelihood of leaving for urban centres depends on other factors, such as the prospects of employment in urban areas or the expectation to provide for a household.

Demographic effects on migration are not the direct consequence of the demographic makeup per se but are typically driven by the economic and social characteristics of the sourcing and receiving areas. For example, a region with a high population density is most likely to experience outmigration, not because of over crowdedness but because of declining income and employment opportunities or declining agricultural productivity (Hugo, 2011). Other demographic effects include birth rates and death rates (Black *et al.*, 2011). People are more likely to migrate from disease-infested areas with high infant mortality and death rates. Likewise, the demographic structure of the receiving region can influence migration. For example, areas with an ageing population can be attractive because of the demand for labour.

Consequently, the process of urbanisation changes household structures. In urban areas, due to delayed marriage, lower fertility rates and desire for personal space, families become smaller, with only nuclear families living under one roof as opposed to extended families in rural areas (Njoh, 2003). Social factors, such as cultural expectations and individual aspirations, push young people toward urban areas (Flahaux and Haas, 2016). For example, in Cape Verde, there is an expectation of returning migrants to contribute positively to society (Åkesson, 2011). Likewise, in Pakistan, Nigeria and Egypt, males migrate to large cities because of economic motivations, while females do so because of marriage or other familial reasons (Hasan, 2010).

Moreover, on average, younger people are more likely to migrate than older people (Black *et al.*, 2011; Hugo, 2011). So, at the onset of a migration inducing event, the demographic makeup of a source area could provide some insight into who will migrate and how many of them. Sometimes, however, the incentive to migrate is purely a result of unfavourable conditions for productivity, such as land degradation or declining rainfall.

Environmental effects on migration act through climate variability. Climate variability, in this case, refers to the fluctuations in climate-related weather events, such as rainfall or droughts. The effect of climate variability on migration acts through crop yields rather than a direct effect on household income (Lilleor and Van den Broeck, 2011). These effects are more pronounced in rural areas than urban areas because of rural areas' dependence on agriculture. Several studies find significant effects of rainfall on crop yield, consumption and income (see, for example, Rowhani et al. (2011) and Ahmed et al. (2011) for Tanzania; Kazianga and Udry (2006) for Burkina Faso; Dercon (2004) for Ethiopia), and of rainfall on migration (see, for example, Henry, Boyle and Lambin (2003) and Henry, Schoumaker and Beauchemin (2004) for Burkina Faso; Findley (1994) for Mali).

Interestingly, Barrios, Bertinelli and Strobl (2010) find a significant positive effect of rainfall on economic growth in Sub-Saharan Africa but not in other developing countries. This can be attributed to the relatively large share of the agricultural sector in the economy and labour force in Sub-Saharan African countries and the dependence on hydropower for electricity. On average, migration due to rare climatic events is short-lived (Black *et al.*, 2011). Most migrants return to their homes after a drought, flood or storm has passed. More importantly, the resulting dynamics of weather events, in terms of who the migrants are and where they end up, depends on the socio-economic characteristics of the societies they are a part of (Tacoli, 2011). So, like the other three factors, environmental conditions alone don't determine migration.

The consequences of urbanisation on energy consumption, therefore, will depend on personal circumstances, the causes of migration and the type of urbanisation. For example, the way new urban residents consume energy will depend on their income and their ability to procure fuel or energy services, but it will also depend on whether they were fleeing war or famine or if their village was reclassified from rural to urban. Either way, for broader energy planning, it is important to understand how these shifts happen, where they are likely to occur, and what can be done to accommodate them. Moreover, the natural growth of the urban population, depends on demographic indicators like fertility rate, mortality rate and female education, and migration depends on different macroeconomic and political factors. And crucially, there is an immediate need for governments to anticipate the effects of these demographic shifts on service provision in urban centres.

2.1.2 Type of urbanisation

The type of urbanisation taking place makes a difference. In Sub-Saharan Africa today, one of the critical drivers of urbanisation is high urban fertility rates (Cobbinah, Erdiaw-kwasie and Amoateng, 2015), instead of historical Western urbanisation, which was driven by rural-urban migration (McGranahan *et al.*, 2009). This is particularly important regarding energy consumption because whether people come from rural areas to urban areas or are born to an urban family will determine how they use their energy (see, for example, Miah et al. (2011) for differences in household energy use in Bangladesh). For example, a new urban family will tend to use traditional fuels as it did in rural areas because of cultural factors, income and access limitations. On the other hand, a new member of an urban family will use energy as the rest of the household, only limited by the household's inherent ability to use certain types of energy. This way, the significant factors in determining the energy consumption of cities because of urbanisation will include whether the household is in a slum or not, whether this household has access to the grid, and whether this household is in an area targeted by specific government policies

2.1.3 Urbanisation and service provision

The factors that determine urbanisation will ultimately influence service provision in urban areas. The urbanisation process demands the development of critical infrastructure to accommodate the needs of an increasingly urban population. Urbanisation will increase demand for energy, water, transport, education, waste management, ICT services and security. Providing these services and satisfying the needs of the urban population can be beneficial to economic growth and stability. In that respect, energy provision is crucial. Energy provision has a well-established positive relationship with economic growth and is a vital ingredient for successful industrialisation (see, for example, Stern (2004); Chontanawat, Hunt and Pierse (2008); Odhiambo (2009); Odularu and Okonkwo (2009); Belke, Dobnik and Dreger (2011)).

Additionally, whether these services are provided and how they are used also depends on specific economic, institutional and demographic factors. For example, in industrialised economies, new urban residents will seek employment in industry, which means higher incomes and a tendency toward a more energy-intensive lifestyle (Zhao and Zhang, 2018). In contrast, new urban residents in a country dominated by the agricultural sector might seek employment in the informal sector with its associated uncertainties, which means income volatility and dependence on cheap traditional fuels. The institutional structure can determine if rural residents are willing to leave for urban areas at all. For example, if more democratic governments favour rural electrification, living under democratic leadership can induce economic activity in rural areas, increase the quality of life, and incentivise rural residents to stay. Also, the number of people between the ages of 25 and 54 determines the size of the labour force, how many people are moving around to work, and, hence, the demand for transport networks and transport fuels (Black *et al.*, 2011). Considering these factors, to plan for the inevitable increase in urban populations in developing regions like Sub-Saharan Africa, we must understand how urbanisation affects energy consumption.

2.2 The effect of urbanisation on energy consumption

The relationship between urbanisation and energy consumption has been studied extensively, but there are few studies on Sub-Saharan Africa. The motivations vary depending on the region, but two common themes emerge: climate change and resource use. The authors mostly agree that there is some uncertainty surrounding the potential impacts of urbanisation on energy consumption, hence the need for further research. This uncertainty, however, has not provoked as much interest as other relationships more rooted in economics, such as that between economic growth and energy consumption. Similarly, there are plenty of studies on the effect of urbanisation on carbon dioxide emissions (see, for example, Poumanyvong and Kaneko (2010); Sharif Hossain (2011); Martínez-Zarzoso and Maruotti (2011); Zhu, You and Zeng (2012); Al-Mulali et al. (2013); Shahbaz et al. (2014, 2016); Wang et al. (2014); Sadorsky (2014); Sheng and Guo (2016); Y. Wang et al. (2016); Q. Wang et al. (2016); Rafiq, Salim and Nielsen (2016); Behera and Dash (2017); Bekhet and Othman (2017); He et al. (2017); Ouyang and Lin (2017))[2]. Most of the studies on the effect of urbanisation on energy consumption use econometrics with national-level data.

2.2.1 Early studies using econometrics

The first investigation of this type on the effects of urbanisation on energy consumption was by (Jones, 1989). Jones (1989, 1991) uses data from 1980 for 59 developing countries and applies cross-sectional regression analysis to find the effect of urbanisation on energy consumption. The results of the two studies revealed a positive impact of urbanisation on energy consumption: a 1% increase

[2] An argument can be made to include the studies on the relationship between urbanisation and carbon dioxide emissions in this literature review as it would be sensible to view carbon dioxide emissions as a proxy for energy consumption. However, this is highly dependent on the country, region or group of countries being investigated. For example, in low-income countries, a marginal increase in energy consumption would correspond to a large increase in carbon dioxide emissions, because of low efficiency technologies, while the opposite is true in high income countries with high efficiency technologies.

in urbanisation increases energy consumption by 0.35% to 0.48%. This study set the rubric for investigating the effects of urbanisation on energy consumption. The research that followed used the econometric estimation methods that were being developed in parallel, but the general methodology remained the same.

Among the studies that followed, Burney (1995), Lariviere and Lafrancè (1999) and York, Rosa and Dietz (2003) used similar cross-sectional regression analysis for 93 developed and developing countries, 45 cities in Quebec in Canada and 138 countries, respectively. Burney (1995) and York, Rosa and Dietz (2003), similarly to Jones (1989, 1991), find that urbanisation positively affects electricity consumption in the majority of countries in their respective studies, while Lariviere and Lafrancè (1999) find that high-density cities use less electricity per capita than low-density ones. This makes sense because there is a higher probability of cohabitation in high density cities. Furthermore, Parikh and Shukla (1995) and Imai (1997) were the first to use panel data on a group of developed and developing countries and countries with a population of over 10 million in 1995, respectively. Both find that urbanisation increases energy consumption. The studies that followed used panel data and more advanced estimation methods (a comprehensive summary table of the literature is in Appendix A).

There was general agreement among the authors of the earlier studies that urbanisation increases energy consumption: as more people move to urban areas, energy consumption increases through increased economic activity, increased use of modern energy – either electricity or energy-intensive transport – and the subsequent adoption of energy-intensive lifestyles. Perhaps, this consensus was reached because of what the data revealed: at the time, the efficiency of modern energy technologies was consistent throughout the world; or maybe, because of the rudimentary estimation techniques available. Either way, the different economic, social and political structures and other factors that affect energy use across countries allow for some scepticism regarding this consensus. A significant development was the use of the stochastic impacts by regression on population, affluence and technology (STIRPAT) model. The STIRPAT model is a extension of the IPAT (the environmental impact (I) of human activity is the product of population (P), affluence (A) and technology (T)) identity, which was developed to analyse the "effects of human activity on the environment" (York, Rosa and Dietz, 2003). This was first used by York, Rosa and Dietz (2003) to find the effects of urbanisation on the energy footprint of countries. The studies that followed adopted the STIRPAT model and used an assortment of econometric estimation methods to find the impact of urbanisation on both energy consumption (see, for example, York (2007a); Liddle and Lung (2010); Poumanyvong and Kaneko (2010); Poumanyvong, Kaneko and Dhakal (2012); Zhang and Lin (2012); Salim and Shafiei (2014); Li and Lin (2015); Zhou et al. (2015); Shahbaz et al. (2015); Liu et al. (2017); Shahbaz, Chaudhary and Ozturk (2017)) and carbon dioxide emissions (see, for example, Poumanyvong and Kaneko (2010); Martínez-Zarzoso and Maruotti (2011); Zhang and Lin (2012); Zhu, You and Zeng (2012); Zhou et al. (2015); Shahbaz et al. (2016); Sheng and Guo (2016); Abdallh and Abugamos (2017)). The STIRPAT model is important in its transformation of the IPAT identity from an accounting equation (where I = PAT) to a stochastic equation, wherein regression analysis could be used to estimate the effects of each explanatory variable (P, A and T) on the dependent variable (I). However, for the objectives of this thesis, its only significance is its role as the model of choice for a considerable number of studies on the subject. The use of the STIRPAT model seems not to affect the conclusion of the analyses. The estimation method, however, does.

2.2.2 Estimation methods

The most common estimation method used in the literature is Ordinary Least Squares (OLS) (see, for example, Burney (1995); Parikh and Shukla (1995); York, Rosa and Dietz (2003); Liddle (2004); Karathodorou, Graham and Noland (2010); Al-mulali, Binti Che Sab and Fereidouni (2012); Zaman et al. (2012); Al-Mulali et al. (2013); Sadorsky (2013); Liddle and Lung (2014); Yan (2015); Azam et al. (2015); Li and Lin (2015); Ma (2015); Q. Wang et al. (2016); Yang, Liu and Zhang (2017)). OLS estimates the magnitude of the effect of the explanatory variable on the dependent variable by calculating the ratio of the covariance between the explanatory variable and the dependent variable to the variance of the explanatory variable[3]: how the explanatory and dependent variables vary together with respect to the variation in the explanatory variable. This method is generally used with cross-sectional data (data collected by observing different variables for many subjects at the same point in time). Other methods are used for panel data (data that looks at how different variables for many subjects change over time). One popular method is Fixed Effects (FE) estimation (see, for example, Parikh and Shukla (1995); Liddle (2004); Zhang and Lin (2012); Sadorsky (2013); Lin and Ouyang (2014); Li and Lin (2015); Ma (2015); Yan (2015); Zhou et al. (2015); Yang, Liu and Zhang (2017)). Another method, an extension of OLS, is pooled-OLS (POLS) (see, for example, Parikh and Shukla (1995); Sadorsky (2013); Li and Lin (2015); Ma (2015); Yan (2015); Yang, Liu and Zhang (2017)). It is essential to call attention to the fact that, although I later observe that different estimation methods give similar results for the same region, and due to the nature of the disaggregated data used in the literature and the limitations of the estimation techniques, the results of the analyses do depend on the estimation method used. This is pointed out by Sadorsky (2013), who, in a study to estimate the effects of urbanisation on energy intensity while controlling for income and industrialisation using pooled-OLS, FE and First Differences estimation, finds mixed results and concludes that the results depend on the estimation technique. This is corroborated by R Elliott, Sun and Zhu (2014), who claim "the impact of urbanisation on energy intensity is sensitive to the econometric modelling approach." This observation pertains to methods estimating the magnitude and significance of the effect of urbanisation on energy use but not methods assessing short or long-run dynamics between the two variables.

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[3] The covariance is the sum of the products of the difference between the observations of the explanatory variable (x_i) and its mean ($\bar{x}$) and the difference between the observations of the dependent variable (y_i) and its mean ($\bar{y}$). The variance is the sum of the square of the difference between the observations of the explanatory variable (x_i) and its mean ($\bar{x}$). The OLS estimator $= \frac{\sum_{i=1}^{N}(x_i - x)(y_i - \bar{y})}{\sum_{i=1}^{N}(x_i - x)^2} = \frac{\not{N} \cdot cov(x_i, y_i)}{\not{N} \cdot var(x_i)}$.

One such method in the literature used to find short, and long-run dynamics between the variables in the presence of non-stationarity is the error correction model. This method is used when the variables in the model are believed to be cointegrated. This method is premised on the assumption that the values of the dependent variable we observe are different from the long-run equilibrium value, and this deviation is influential in the short-run. And these observed values are potentially dependent on lagged values of the explanatory variable (maybe because the dependent variable takes time to react to changes in the explanatory variable) and lagged values of the dependent variable itself. Using this method, Halicioglu (2007) finds that urbanisation causes residential electricity consumption in Turkey in the long run. Liu (2009) and Al-Mulali et al. (2013) find similar results for energy consumption for China and a group of Middle Eastern and North African (MENA) countries, respectively. And for a group of ASEAN countries, Wang, Chen and Kubota (2015) find that urbanisation causes energy consumption in the short run. Moreover, other studies find that urbanisation causes energy consumption in the short and long run (Wang *et al.*, 2014; Shahbaz *et al.*, 2015; Sodri and Garniwa, 2016; Shahbaz, Chaudhary and Ozturk, 2017). A bidirectional causality between urbanisation and electricity consumption was found by Gam and Ben Rejeb (2012) and Solarin and Shahbaz (2013) for Tunisia and Angola, respectively, while Shahbaz and Lean (2012) found that, for Tunisia, urbanisation has no significant impact on total energy consumption in the short run.

Another method used in the literature to determine causality is the Granger-causality method. Using this method, Mishra, Smyth and Sharma (2009) and Bakirtas and Akpolat (2018) conclude that urbanisation causes energy consumption for 9 Pacific Island countries and a group of developing countries, respectively. In a study looking at the effect of urbanisation on energy consumption for India, Ghosh and Kanjilal (2014) use Granger-causality and control for per capita GDP. The results reveal a unidirectional causality from energy consumption to economic growth and from economic growth to urbanisation. From this result, we can conclude that energy consumption causes urbanisation through economic growth for India. In studies using different dependent variables, Rafiq, Salim and Nielsen (2016) find that urbanisation significantly increases energy intensity in 22 increasingly urbanised emerging economies, Liddle and Lung (2014) find that electricity consumption Granger-causes urbanisation for a group of 105 countries, and Michieka and Fletcher (2012) find that urbanisation Granger-causes electricity consumption from coal sources for China. For the same methodology, different results arise due to the choice of region.

2.2.3 Regional variation and level of development

It makes sense for similar estimation methods to give different results for different regions and for different estimation methods to provide similar results for the same region. The literature available allows for such a comparison to be made. The literature shows noticeable similarities in the results of analyses of the same region. This can be illustrated by the following studies, all of which use data from Malaysia. Bakirtas and Akpolat (2018) and Shahbaz et al. (2015) find that urbanisation Granger causes energy consumption. Using a similar method, albeit a different dependent variable, Bilgili et al. (2017) conclude that urbanisation positively influences energy intensity[4]. Beyond causality, Azam et al. (2015) finds that urbanisation has a positive, but not statistically significant, impact on energy consumption, while Al-mulali, Binti Che Sab and Fereidouni (2012) find a long-run positive bidirectional relationship between urbanisation and energy consumption. Likewise, studies considering groups of countries in the same region or with similar levels of development (Malaysia included), with analysis conducted for the group, show some consistency in the results: Jorgenson, Rice and Clark (2010) concludes that urbanisation is positively associated with energy consumption for a group of 57 less developed countries; Wang, Chen and Kubota (2015) find a short-run causality from urbanisation to energy consumption for ASEAN countries; Rafiq, Salim and Nielsen (2016) find that urbanisation significantly increases energy intensity for 22 increasingly urbanised emerging

[4] Energy intensity is energy consumption per unit of GDP. So, technically, urbanisation has a negative influence on *energy productivity*.

economies. More importantly, regional variations in some cases reflect variations due to levels of development. This is most evident in China.

Within the existing literature, many studies attempt to estimate the relationship between urbanisation and energy consumption in China (see, for example, Liu, 2009; Zhang and Lin, 2012; Zhou et al., 2012, 2015; Jiang and Lin, 2012; Michieka and Fletcher, 2012; Liu and Xie, 2013; R Elliott, Sun and Zhu, 2014; Wang et al., 2014; Lin and Ouyang, 2014; Yan, 2015; Ma, 2015; Q. Wang et al., 2016; Elliott, Sun and Zhu, 2017; Fan, Zhang and Wang, 2017; Yang, Liu and Zhang, 2017; Liu et al., 2017; Zhao and Zhang, 2018). Taking regional differences into account, Zhang and Lin (2012) find that urbanisation increases energy consumption, with the magnitude of the effect diminishing from the Western (low-income region) to the Eastern region (high-income region). This essentially means that the extent of the impact of urbanisation on energy consumption is smaller in the high-income Eastern part of China. This could be explained in two ways: due to high barriers to entry, the increase in the urban population in the Eastern, high-income region could be primarily due to natural growth, where the new urban population would consume energy in similar ways to the existing urban population; or because of better infrastructure, there would be better access to more efficient modern energy services in the Eastern, high-income region. On the other hand, using a similar regional analysis, Zhou et al. (2015) find that urbanisation increases energy consumption for the whole sample. Yet, the urbanisation variable is significant for the Central and Eastern regions and insignificant for the Western region.

Similarly, some provincial studies of China have highlighted variations in the effect of urbanisation on energy consumption due to regional differences. R Elliott, Sun and Zhu (2014) find that urbanisation has a negative impact on energy consumption in the more developed Eastern region and a positive effect on the Central and Western regions. This can be explained by barriers to entry, as before, coupled with increases in the efficiency of energy services.

Moreover, emphasising differences in the level of urbanisation, Q. Wang et al. (2016) find that urbanisation leads to increases in energy consumption but claim that the extent of the increase is not consistent between provinces and depends on how urbanised the province already is (for more provincial studies for China, see Lin and Ouyang (2014); R Elliott, Sun and Zhu (2014); Wang et al. (2014); Yan (2015); Q. Wang et al. (2016); Elliott, Sun and Zhu (2017); Liu et al. (2017)). The studies on China are particularly important because of the economic growth the country has experienced in the last three decades. The regional differences in China can reveal some similarities between China's less developed Western region and some landlocked Sub-Saharan African countries. There's also the similarity of long-term one-party rule. In addition to regional and developmental variations within a country, there is evidence that shows variations due to the level of development across countries.

One such example is Li and Lin (2015), who use a panel dataset for 73 countries. Categorising the countries into four income groups, the authors find: that urbanisation decreases energy consumption for low-income countries; urbanisation significantly increases energy consumption in middle- and low-income and high-income countries; urbanisation doesn't considerably affect energy consumption for middle-/high-income countries. In a similar study, using a smaller sample of Middle East and North African countries, Al-Mulali et al. (2013) find a positive relationship between urbanisation and energy consumption for high-income countries and a negative relationship for low-income countries, and the significance of the relationship depends on the level of development. These results are intuitive: in low-income countries, where residential energy consumption accounts for a significant portion of total energy consumption, members of low-income households, who are most likely to migrate to urban areas, are more likely to use inefficient fuels and energy technologies; once in urban areas, however, they are more likely to consume energy more efficiently, hence reducing their total energy consumption.

These findings are similar to those of Al-mulali, Binti Che Sab and Fereidouni (2012), who, in a similar study that looks at seven regions of the world, find both a negative long-run relationship and no relationship in low-income countries. Furthermore, the authors also find that countries with high urban populations show a more significant long-run relationship than countries with low urban populations (here, a large urban population could mean high income, and a low urban population could mean low income). Likewise, for a group of 99 countries, Poumanyvong and Kaneko (2010) find that urbanisation increases energy consumption in the middle- and high-income countries and decreases energy consumption in low-income countries. On the other hand, looking at transport and road energy use, Poumanyvong, Kaneko and Dhakal (2012) find that the most considerable effect of urbanisation on road energy use is in low- and high-income countries. This result is sector-specific and not necessarily incompatible with the previous studies. In low-income countries, new urban residents arriving from rural areas, where they would have relied chiefly on traditional modes of transport for relatively short commutes, would be forced to use fuel-consuming transport for longer commutes inherent to urban areas. In high-income countries, where a large portion of the increase in urban residents can be explained by natural growth, an increase in the urban population essentially means an increase in the number of people with the same consumption habits. In a slightly different analysis looking at the effect of urbanisation on energy production in 14 South and East Asian countries, York (2007b) finds that the impact of urbanisation is highest in the least urbanised countries and lowest in moderately urbanised countries. This, again, makes sense because, in low-urbanised areas, an increase in the absolute number of people in urban areas constitutes a larger percentage increase. Alas, not all the studies can attribute their results to differences in income, development or level of urbanisation.

2.2.4 Data-driven results

Some results can be attributed to the data, choice of explanatory variables, or the model used. In a study looking at 10 Asian countries using data from 1990 to 2014, Bilgili et al. (2017) investigate the relationship between energy intensity and urbanisation. The analysis results show that urbanisation has a negative effect on energy intensity in India and China in the long run (urbanisation increases energy productivity). On the other hand, urbanisation positively affects energy intensity in Malaysia, Nepal, Philippines, South Korea, Thailand and Vietnam (urbanisation decreases energy productivity). In Indonesia and Bangladesh, urbanisation has no significant effect on energy intensity. There is no noticeable trend in the results. For each of the three possible outcomes – negative, positive or no effect – there is no homogeneity between the countries in terms of development, total GDP or level of urbanisation. We would expect, for example, South Korea and Thailand to have similar results to China because of the structure of their economies. One possible grouping factor, however, is population: India and China both have populations well over 1 billion; Malaysia, Nepal, Philippines, South Korea, Thailand and Vietnam have populations ranging from 30 to 100 million; Indonesia and Bangladesh have populations of 260 million and 160 million, respectively. This argument, although not very convincing at first, is given credence by the fact that the model used does not control for the total population. As I pointed out earlier, the ambiguity in the results can be attributed to both the data and the estimation techniques.

Furthermore, the data doesn’t usually tell the whole story. It is, therefore, vital to consider the context and the processes inherent in the interacting variables. One way to achieve this is by looking at how urbanisation could affect energy consumption, not just whether it does and by how much.

2.2.5 Urbanisation pathways and context

In an attempt to provide some insight into how urbanisation could potentially affect energy use in China, a study by Zhao and Zhang (2018) investigates the effects of urbanisation on energy consumption during the period 1980 to 2010. To find the overall relationship between urbanisation and energy consumption, the authors conducted a time series regression analysis: energy consumption as the dependent variable; urbanisation (the urban population as a percentage of total population), economic growth (GDP) and industrialisation (share of industry value added to GDP) as the explanatory variables. The regression analysis results reveal that a 1% increase in the urban population was complemented by a 1.4% increase in energy consumption. In addition, the authors identify three main pathways by which urbanisation happens or through which urbanisation causes energy consumption: urban spatial expansion (affects construction and infrastructure-related energy consumption), urban transportation (involves transport energy use), and transition in urban lifestyle (affects energy consumption in the residential sector). The importance of this study is the identification of the pathways through which urbanisation affects energy consumption.

It would be fair to expect these pathways to lead to different results or to have other implications in the Sub-Saharan African context. Urban spatial expansion: new urban residents, who are more likely to be urban poor, settle into modest housing; new buildings and infrastructure are not (and would not be) built to cater to the poor or the newly urbanised rural populations. Urban motorisation: the increase in urban motorisation would more likely drive demand for public transport than car ownership. Energy-intensive lifestyles: this will depend on where new urban residents settle, which is also related, in more ways than one, to access to modern energy; grid-connected areas in urban centres in low-income countries might not be affordable; on the other hand, the further away from urban centres the new urban poor settle, the more demand there will be for public transport to access markets and employment; the energy intensity of the household (or household members) will ultimately depend on other factors. There’s also the nature of jobs and structure of the economy: in Sub-Saharan Africa, most of the able and working-age newly urbanised population would more likely first assume employment in the informal sector (Cobbinah, Erdiaw-kwasie and Amoateng, 2015). In this case, identifying the path of urbanisation is important. It highlights the fact that context matters: how urbanisation affects energy consumption in China is not necessarily how it will affect energy consumption in Nigeria.

Regrettably, some studies, by not considering context, lack informed justifications of the results. Indeed, empirical analyses carry some truth, but the context within which the results develop is also important. One example is a study by Rafiq, Salim and Nielsen (2016) that looks at the effects of urbanisation and other variables on carbon dioxide emissions and energy intensity in 22 emerging economies using data from 1980 to 2010. The authors investigate the effects of population, per capita GDP, renewable energy, non-renewable energy, trade liberalisation and urbanisation on carbon dioxide emissions and energy intensity. The results of the analysis show that population density increases energy intensity and carbon dioxide emissions. In addition, urbanisation significantly increases energy intensity but does not affect carbon dioxide emissions. The authors attribute this finding to “maybe” the recent trends in adopting cleaner energy technologies. This conclusion is lacking: the average renewable energy use as a percentage of total energy use of the countries in the sample is 4.4% (including hydro). Therefore, it is unlikely that the limited effect of urbanisation on carbon dioxide emissions would be due to the recent adoption of cleaner energy, despite the significant positive impact on energy intensity (especially considering that hydro adoption is not new). Context is crucial in studies that consider groups of countries, especially for developing countries. The homogeneity in urbanisation rates and the economic structure across developed countries does not exist in developing countries. In Sub-Saharan Africa (SSA), for example, urbanisation rates range from 12% to 72%, electrification rates range from 7% to 84%, and economies are highly dependent on natural resources.

2.2.6 Urbanisation and energy consumption in Sub-Saharan Africa

There is considerably less literature on Sub-Saharan Africa and the poorer regions of the world looking at the relationship between urbanisation and energy consumption. For example, there are several studies investigating the effect of urbanisation on energy consumption in the "Global South" (see, for example, Jones (1989, 1991), York (2007b), Jorgenson, Rice and Clark (2010), Sadorsky (2013), Azam et al. (2015), Bakirtas and Akpolat (2018) for groups developing countries; Gam and Ben Rejeb (2012) and Shahbaz and Lean (2012) for Tunisia; Ghosh and Kanjilal (2014) for India; Shahbaz, Chaudhary and Ozturk (2017) for Pakistan; Shahbaz et al. (2015) for Malaysia), but only two for Sub-Saharan African countries (Adom, Bekoe and Akoena (2012) for Ghana; Solarin and Shahbaz (2013) for Angola), both of which look specifically at electricity consumption.

Studies on the relationship between urbanisation and energy consumption in Sub-Saharan Africa are limited in their number and scope. In one of the two studies that look at a Sub-Saharan African country, Solarin and Shahbaz (2013) study the causal relationship between electricity consumption, economic growth and urbanisation in Angola from 1971 to 2009. The ARDL bounds test is applied to test for cointegration and the existence of a long-run relationship between the variables, followed by the vector error correction model (VECM) causality test to examine the causal relationship between the three variables. The result most relevant to this thesis is the existence of bidirectional long-run causality between urbanisation and electricity consumption. It is also important to mention that the study's primary objective is to determine the causality between electricity consumption and economic growth, and urbanisation is used as a control variable. In a similar study, Adom, Bekoe and Akoena (2012) attempt to find the factors that have historically affected domestic electricity demand in Ghana by using a model that specifies electricity consumption as the dependent variable, and per capita GDP, industry efficiency, the structure of the economy and urbanisation as explanatory variables. The authors use the ARDL Bounds cointegration method to find the short and long-run relationships between the variables. The results of the analysis show that urbanisation, along with per capita GDP and industry efficiency, is one of the main drivers of domestic electricity consumption in both the short and long-run. Industry efficiency is the only variable that negatively affects electricity consumption. As such, the authors recommend implementing the necessary efficiency standards for the industrial sector. No recommendations are made regarding urban, rural or residential electricity provision. The same is true for the previous study. This, in a way, highlights one of the limitation of using aggregate-level data to recommend policy options that are bound to have micro-level effects.

2.2.7 Non-econometric approaches

Other studies look at the effects of urbanisation on energy consumption but use different methods. One study by Zhou et al. (2012) uses a quantitative assessment method on the impact of urbanisation on the residential sector, transportation and building materials industry in China for a period spanning 20 years. Another study by Fan, Zhang and Wang (2017) uses Divisia decomposition analysis to find the impact of urbanisation on residential energy consumption in China. Other studies on China include Duan et al. (2008), who developed and used the Energy Consumption Unit Geometric Average (ECUGA) elasticity coefficient to analyse the relationship between urbanisation and energy consumption, and Li, Liu and McKinnell (2006), who look at the relationship between urbanisation and building energy consumption through the role of building codes. A study on urban energy use used statistical and correlation analysis on data from 274 cities across 60 countries to estimate the factors that determine the urban energy use (Creutzig *et al.*, 2015). Other studies, such as Güneralp et al. (2017), use modelling to estimate the effect of global scenarios of urban density to 2050 on building energy use. Most studies, however, use econometrics to gauge the overall impact of an increase in the urban population on national level energy consumption.

The literature on the effect of urbanisation on energy consumption is inconclusive. Some studies suggest a positive association, and some studies suggest a negative association and others suggest causality. One way to get a clearer picture is to use city level and sectoral data to measure the direct effect of the increase in the urban population on urban energy use (see, for example, Sodri and Garniwa (2016)). More importantly, there is a clear gap in the literature for studies on Sub-Saharan Africa. This is particularly important because Sub-Saharan Africa is set to experience a significant increase in urban population in the next three decades. Knowing how this urbanisation will affect energy consumption in cities, countries, and the continent will be crucial to energy provision and providing the necessary infrastructure. The effectiveness of the infrastructure and efficiency with which energy is provided depends on the institutions in place. The type and quality of institutions are critical to service provision, and good quality institutions will be necessary to design and implement energy provision policies, both in urban and rural areas.

2.3 Institutions and electricity access

2.3.1 Institutional capacity and public service provision

Policy, institutional capacity, and governance play a crucial role in the delivery of public services. This is especially true in Sub-Saharan Africa where there is a growing need to expand access to services and infrastructure. In Senegal, for example, the Senegalese Rural Electrification Action Plan, a well-funded, innovative electrification strategy, had limited effects on electrification levels in the country (Mawhood and Gross, 2014). Some identified barriers include inconsistent political commitments, lack of support from government executives, and poor institutional capacity. Despite the plan’s laudable design, the country’s institutional set-up proved intractable. Similarly, in the early 2000s, the Kenyan parliament introduced around five bills and established “development authorities” to tackle rural development, yet there’s little to show. The operation of the development authorities was mired by corruption, government interference and mismanagement (Sebitosi and Pillay, 2005a). Even when considering Kenya’s new Kenya Slum Electrification Program, which has a solid political foothold by being part of Kenya Vision 2030, new insights reveal that the political inclusion of slum dwellers as citizens and residents of Nairobi is crucial to the success of the program (de Bercegol and Monstadt, 2018). Similar stories can be told about other Sub-Saharan African countries. Public service provision on the continent and around the world, such as electricity supply, depends on the quality of institutions, and, where feasible, is commonly used as a tool for political gain.

The delivery of public services depends on institutional quality, government accountability and inclusiveness. Inclusiveness is a measure of how well public service provision reflects the majority’s interests over an elite minority. A considerable amount of literature suggests a positive correlation between institutional quality and public service provision (see, for example, McGuire and Olson (1996); Lake and Baum (2001); Adserà, Boix and Payne (2003); Deacon (2003); Brown (2006); Rothstein and Teorell (2008); Harding and Stasavage (2014)). How well governments function depends on regular elections to ensure a credible threat for politicians and access to information to check corruption and mismanagement (Adserà, Boix and Payne, 2003). More inclusive governments with regular elections provide education (Brown, 2006), infrastructure (Harding, 2015), and security far better than less inclusive (non-democratic) governments (Deacon, 2003). These conclusions are premised on, and provide supporting evidence for, the intuitive understanding that democracy offers a mechanism by which citizens can hold their governments accountable for providing public services. Essentially, in a democracy, public officials act under the constraint of being voted out of office (Bueno De Mesquita *et al.*, 2001, 2002). Consequently, under electoral pressure, public officials strive to satisfy the needs of as large a portion of the population as possible.

2.3.2 Democratisation and electricity access

There is, however, some suggestion that better institutions are not always the answer. A growing literature on the effect of institutional health on the provision of public services and infrastructure projects in developing countries shows mixed results. For example, Isham, Kaufmann and Pritchett (1997), who studied the link between civil liberties and the performance of World Bank-funded government projects, found that civil liberties increase the efficiency of project performance through increased citizen voice, even when controlling for political liberties (the level of democracy). Essentially, the more of a say people have (not in politics), the more efficiently the government executes projects. Interestingly, however, the authors also find that democracy has a negative and statistically insignificant effect on project efficiency.

Another study finds weak evidence for a positive impact of institutional quality on electricity access for Sub-Saharan African countries (Onyeji, Bazilian and Nussbaumer, 2012). The authors try to estimate the effects of financing, population, and institutional quality on energy access. Institutional quality is represented using three different indices: corruption perception index (CPI), regulatory quality index (RQI) and government effectiveness index (GEI). The analysis is carried out for two groups, one controls for gross domestic savings and the other controls for energy-related gross fixed capital formation (GFCF). Only GEI is statistically significant for the first group of the three institutional quality variables, while RQI and CPI have negative coefficients. None of the three institutional quality variables is statistically significant for the second group, and RQI and CPI have negative coefficients. In addition, the authors point out that for a GEI score between -1 and 0 (range -2.5 to +2.5), countries not in Sub-Saharan Africa have much higher access to electricity than countries in Sub-Saharan Africa. This, they posit, is due to non-Sub-Saharan African countries prioritising universal electricity access and Sub-Saharan African countries prioritising regional power pools over rural electrification. This proposition is plausible. Two groups of countries with similar institutional qualities can achieve different electricity access levels by adopting different policies.

The process of democratisation is not a hard and fast solution either. Bäck and Hadenius (2008) find that the effect of democratisation on administrative capacity depends on the level of democracy: negative for low levels of democracy, non-existent for median levels of democracy, and strongly positive for high levels of democracy. This essentially means that non-democratic countries experience adverse effects on state administrative capacity because of the process of democratisation. Assuming the correlation between democracy and income holds over time (Bueno De Mesquita *et al.*, 2001), low-income Sub-Saharan African countries can expect to experience inefficiencies in administrative capacity due to the process of democratisation. This, as a result, can influence how efficiently and frequently governments implement infrastructure projects. On the other hand, in a non-democratic low-income country, the lack of a democratisation process means that state administrative capacities remain low but maintain their respective efficiencies (read inefficiencies).

So, democratic institutions, by several measures, don’t necessarily increase energy access, political liberties hurt project implementation efficiency, and the potential effect of the democratisation process on state administrative capacity in developing countries is negative. This means that low-income countries with low levels of democracy, even with genuine democratisation, cannot expect to have well-functioning, efficient governments and therefore should not expect much with regard to infrastructure projects or service provision.

But there is hope in the incentives that influence how politicians act. We know that politicians acting under electoral constraints do so in such a way as to secure votes. They operate under the threat of being voted out of office. Whether this is a short-term or long-term incentive depends on the length of election cycles and the fairness of elections. The actions of non-democratic leaders, on the other hand, are constrained by different incentives: the short-term stimulus to maintain absolute power. Also, it’s in the interest of an autocrat to provide public goods (McGuire and Olson, 1996). At least to the extent that benefits his (or her) hegemony. We can, therefore, assume that non-democratic governments only face the threat of large-scale, anti-government protests. Under such a constraint, the government's actions would compel it to act in such a way to reduce the possibility of demonstrations and maintain power. This can be achieved in several ways, some violent, some not. One non-violent way is to commission, from time to time, large-scale infrastructure projects that improve public service provision.

The choice of service is determined by the government’s financial capacity, as well as the anticipated placating effect on the population: whether the service can be credited to political intervention, whether the service is visible, and whether the service outcomes are easily “attributable to political intervention” (Batley and Mcloughlin, 2015, p. 278). Electricity, despite the associated costs, is a real crowd-pleaser. Unlike education and health, its effects are immediate, and its existence is verifiable (Mani and Mukand, 2007). And, as discussed in Chapter 5, electricity infrastructure projects serve a dual purpose for non-democratic governments: appease the urban population and provide an opportunity for rewarding government supporters.

2.3.3 Politics and electrification

Electricity is commonly used as a political tool. Electricity provision can be manipulated to influence the outcome of elections. For example, in India, state governments direct electricity to constituencies holding special elections, and manipulation of the power supply by the central government is evident in those same constituencies and in states where the government has a slight majority (Baskaran, Min and Uppal, 2015). Also, Min and Golden (2014) find that in Uttar Pradesh, India’s most populous state, there is a surge in electricity losses in periods just before state assembly elections and that the ruling party is more likely to retain its assembly seats the higher the losses are in the district. Essentially, incumbent parties direct more flat-rate and unbilled electricity to customers in a particular district to secure their votes. In India, having access to electricity can depend on where the ruling party lies on the political spectrum. Aklin et al. (2015) find that slums in states with left-leaning governments, on average, have better access to electricity than slums in states with right-wing governments. Corruption plays a part, too: slums in states with low corruption have better access to electricity. Both findings are intuitive. Left-leaning governments rely on the votes of low-income households, which are primarily located in urban slums. And suppose corruption is rampant at the state administrative level. Then it’s likely there’s corruption within the utility, which means the utility is less efficient (see Dal Bó and Rossi (2007) for proof). Essentially, firms use more inputs to produce a certain level of output. The effect of corruption on firm efficiency is more manifest than ownership type, macroeconomic stability or respect for property rights.

Similarly, there is evidence of aid distribution for political gain by ruling parties during or prior to elections in Ghana. During the 2000 election, Ghana's ruling party, the National Democratic Congress, saw a significant increase in votes in constituencies that received electrification as part of the party's aid allocation strategy (Briggs, 2012). Therefore, electricity can be used as a political tool by directly controlling the supply of electricity or using development finance to electrify underserved areas. Even with a dominant incumbent, electoral competition drives governments to invest in public services to gain as large a share of the votes as possible (Rosenzweig, 2015). The existence of even a mild threat incentivises the government to prioritise underserved populations to remain in power.

Furthermore, politicians can use their legislative powers to guarantee power supply for their constituents because of supply constraints and service level inefficiencies due to theft, corruption, and flat-rate pricing. For example, the 2003 Electricity Act in India was introduced to encourage private electricity generation by industrial consumers (Joseph, 2010a). This legislation was introduced after the fact. Because of the constant decline in quality of service from the grid, industrial consumers were more and more likely to rely on private, on-site, reliable electricity generation. By encouraging more industrial consumers to produce their own electricity on-site, the government was getting reliable electricity generation for the industrial sector without jeopardising supply to the household sector and risking the support of key constituencies. Unsurprisingly, this political meddling has created distrust among voters, especially those who have experienced several elections (Narendranath, Shankkari and Reddy, 2005). These actions should come as no surprise because there is plenty of evidence that politicians tend to reward their core supporters, even in the more developed democracies (see, for example, Bracco et al. (2015); Kauder, Potrafke and Reischmann (2016).

Governments acting under electoral constraints are keen to show their commitment to service provision to win votes. The number of votes an incumbent party receives relates to how well voters perceive the party is performing (Cole, Healy and Werker, 2012). How informed voters are of institutional performance is crucial. One consequence of the lack of information is vote-buying, the preferred strategy for targeting poorer, less knowledgeable voters (Jensen and Justesen, 2014; Keefer and Vlaicu, 2017). In developing countries, vote-buying can replace public service provision as the strategy of choice to win elections (Khemani, 2013; Kramon, 2016). Vote-buying, however, is generally only practised if public funds could be exploited for the purpose (Kramon, 2016). Information, therefore, on performance and public spending is indeed crucial.

However, studies on the effect of information on citizen participation are inconclusive. Some studies suggest that informed citizens, on average, are more likely to vote and participate in the political process (Brady, Verba and Lehman Schlozman, 1995; Gerber and Green, 2000; Reinikka and Svensson, 2011). Other studies find little evidence of a significant effect of information on poor people (Banerjee *et al.*, 2010; Chong *et al.*, 2011; Lieberman, Posner and Tsai, 2014). More importantly, evidence shows that more informed and active citizens lead to higher levels of service provision (Heller, 2001; Björkman Nyqvist, de Walque and Svensson, 2014). This means that governments, fearing a backlash from informed citizens, tend to provide better services.

So, there are three crucial points to be made. First, an active, informed citizenry would better appreciate a government's service provision efforts and vote accordingly. Second, governments want to provide services with an immediate, verifiable effect – perfect information – to secure those votes. Finally, politicians needing to secure votes using public service provision will target the largest population: the rural, poor population. At this point, we can suggest that politicians acting under electoral constraints will favour rural electrification over urban electrification because of the incentive to secure as many votes as possible in future elections: for democratic governments, rural electrification ranks higher than urban electrification (Nanka-Bruce, 2010; Cook, 2011; Onyeji, Bazilian and Nussbaumer, 2012; Ahlborg and Hammar, 2014; Ahlborg *et al.*, 2015). It can thus be argued that democratic institutions are subjected to electoral constraints, and public service provision is one way of securing votes. To that end, electricity is an effective and verifiable public service. In developing countries, most of the population is poor and rural, and democratic governments are concerned with votes and hence prioritise rural electrification.

2.3.4 Institutional quality and electrification in developing countries

The political drivers of electrification in developing countries are varied. Some of the motivations for electrification projects, like other development programs, stem from international funding and political support. Electrification projects have only recently received priority over other development projects. This can be seen in the World Bank's history of support for rural electrification (Cook, 2011). The bank's initial stance on energy in developing countries was power sector reform, which eventually proved too difficult due to political and capacity barriers. This was abandoned in the mid-1990s. By the late 1990s, with a new emphasis on sustainable development, rural electrification was included as part of larger development projects. Therefore, there was no pressure from international development organisations on governments to pursue electrification until recently.

One telling fact is that energy access did not feature in the Millennium Development Goals. At the national level, political drivers play a part too. Funding for electrification projects does not guarantee implementation. In a qualitative study of the drivers and barriers to rural electrification in Tanzania and Mozambique, Ahlborg and Hammar (2014) find that political priorities are the most significant determinant of rural electrification and renewable energy adoption. The drive for rural electrification stems from political ambitions of rural development and preferential treatment for politicians' hometowns and districts, especially during elections. Hence, democratic elections can potentially increase electricity consumption, but for the wrong reasons.

There is some evidence to suggest a positive relationship between institutional quality and electricity consumption. Ahlborg et al. (2015) investigate the significance of democracy and institutional quality on household electricity consumption in Sub-Saharan African countries. The authors make two compelling hypotheses. The first hypothesis is that the more democratic a country is, the higher the per capita household electricity consumption. This hypothesis follows from the argument that because democratic governments are held accountable by citizens and can be replaced through an election process, they see an incentive in providing public goods to satisfy the electorate's needs to remain in power. And, on average, democratic governments prioritise the needs of the majority – the poor, rural population – over the needs of a "narrow urban elite." The second hypothesis concerns institutional quality: the higher the institutional quality in a country, the higher the per capita household electricity consumption. The argument here is that having democratic institutions in place is not enough to guarantee good public service provision. The existence of corruption and favouritism compromise the performance of democratic governments. For example, corruption is a significant barrier to rural electrification (Ahlborg and Hammar, 2014), and political meddling in electric utilities hurts performance (Karekezi and Kimani, 2002). The results of the study support the two hypotheses: a positive and statistically significant effect of democracy and institutional quality on per capita household electricity consumption.

In a similar study, Brown and Mobarak (2009) look at the effects of regime type on the share of electricity consumption of the residential, agricultural and industrial sectors. They make two hypotheses: democracies create regulatory structures and subsidies that prioritise residential and agricultural consumers over industrial consumers; the impact of democracy on the residential share of electricity consumption is more significant in poorer countries. The argument for the first hypothesis is similar to that of the first hypothesis in Ahlborg et al. (2015). Essentially, government officials under electoral constraints create legislative structures and subsidies that favour a larger segment of the population (residential and agricultural consumers) over smaller segments (industrial consumers). For the second hypothesis, the authors suggest that because the poorest countries in the world have the lowest electrification rates, a move to democracy will have a more significant effect on electricity access. The study results show that democracy has a positive and significant impact on the share of electricity consumed in the residential sector in developing countries. The authors carry out sensitivity and specification tests to strengthen their argument. One such test adds a set of institutional variables to test whether democracy is taking credit for the effect of institutional quality.

Contrary to the results in Ahlborg et al. (2015), none of the institutional variables is statistically significant. As a result, the authors conclude that sectors with less financial influence and more electoral influence benefit from democratisation. There are several problems with this conclusion. First, the authors don't consider the possible efficiency effects: the study uses data from 1973 to 1997, during which production technology efficiency would have increased significantly. Second, the authors identify price manipulation through cross-subsidisation as a means of governments prioritising specific sectors. Electricity is an inelastic good, even more so in Sub-Saharan African countries, where subsidies on electricity are implemented by both democratic and non-democratic governments (see Bekele, Negatu and Eshete (2015) for Ethiopia; see Louw et al. (2008) and Lee (2013) for income elasticity; see Hughes-Cromwick (1985) for own-price elasticity). Subsidising already subsidised electricity is unlikely to increase consumption. Finally, the most significant determinant of household electricity consumption in developing countries is electricity access, not price. If the government subsidises household electricity at the expense of industry, this will benefit households already connected to the grid (Maboshe, Kabechani and Chelwa, 2019). Yet still, cheaper electricity for poor homes connected to the grid is unlikely to inspire a consumption spree. In addition, the conclusion seems to contradict that of the previous studies, which emphasise the tendency of democratic governments to prioritise low-income, low-access rural populations.

Unlike democracies, more autocratic governments, and their policies regarding public service provision, are not constrained by electoral processes. Nonetheless, it is in the interest of an authoritarian leader to provide services, at least to limit any political threats and maintain a functioning economy. (McGuire and Olson, 1996, p. 72) offer a brilliant analogy for this argument:

"*Consider the interests of the leader of a group of roving bandits in an anarchic environment. In such an environment, there is little incentive to invest or produce and, therefore, not much to steal. If the bandit leader can seize and hold a given territory, it will pay him (or her) to limit the rate of his (or her) theft in that domain and to provide a peaceful order and other public goods. By making it clear that he (or she) will take only a given percentage of output – that is, by making himself (or herself) a settled ruler with a given rate of tax theft – he (or she) leaves his (or* *her) victims with an incentive to produce. By providing a peaceful order and other public goods, he (or she) makes his (or her) subjects more productive. Out of the increase in output that results from limiting his (or her) rate of theft and from providing public goods, he (or she) obtains more resources for his own purposes than from roving banditry*."

For the purpose of this thesis, the bandits' leader is an autocratic government (or leader), the territory is a random Sub-Saharan African country, and the victims are the citizens. If we assume no foreseeable onset of democracy, then the only tangible threat to an autocratic government's hegemony is a popular uprising by a relatively educated, urban middle-class (Dorsch and Maarek, 2018). We can also assume that, like the bandit, autocratic governments will respond to the incentive of not having much (control) to keep for themselves. This means that, on average, to remain in power, an autocratic government presiding over citizens in each territory will prioritise the needs of those that pose the most significant political threat: the urban population. Contrary to the hypotheses proposed by Brown and Mobarak (2009) and Ahlborg et al. (2015), it makes more sense for autocratic governments in low-income countries, not democracies, to prioritise the residential sector over other sectors. The literature provides plenty of evidence on how democracies target the poorest households, whether to reward core supporters or acquire more. In Sub-Saharan Africa, within the existing electricity infrastructure, the most significant proportion of access is, in fact to urban households: urban electricity access is on average 70%, while rural electricity access is on average 10%. Therefore, it makes no sense for democratic governments to provide access to subsidised electricity to people, who not only have access but would not be persuaded of political allegiance by a service they already use.

If responding to the incentives they face, autocratic governments are more likely to prioritise urban residents over industrial consumers. Contrary to what Brown and Mobarak (2009) propose, democratic governments tend to adopt policies that favour public services like health and education and overall economic growth (McGuire and Olson, 1996; Lizzeri and Persico, 2004; Deacon, 2009), whereas dictatorships espouse, and rely on, more redistributive policies, such as cash transfers, targeted at politically important groups (Kammas and Sarantides, 2019). The industrial sector, despite its economic clout, represents a political minority. Plus, in response to unreliable or non-existent electricity, industrial actors generate their own (see, for example, Reinikka and Svensson (2002) for public services in general; Fisher-vanden, Mansur and Juliana (2015) for industrial firms in China; Abdisa (2018) for firms in Ethiopia; Joseph (2010) for industrial firms in India; Steinbuks and Foster (2010) for firms in Africa). This has now become standard practice. With unreliable electricity supply, firms that do not invest in self-generation are sure to incur losses (Cole *et al.*, 2018).

Furthermore, electricity provision to the industrial sector drives industrialisation and economic growth (Rud, 2012; Andersen and Dalgaard, 2013). Given the negative effect of lack of electricity on industrialisation, and the likely prospect of losing out on economic growth (a metric that citizens use to judge government performance), it makes no sense for democratic governments to neglect the industrial sector, even if it represents a political minority. On the other hand, autocratic governments, concerned with the short-term gain of maintaining power and potentially knowing that industry will “sort itself out,” can afford to prioritise urban residential electricity over industrial consumers to minimise potential threats of a popular uprising.

Additionally, if industrial firms are required to invest in generation capacity, they will invest less in production capacity and pass the added cost of generation down to the consumer. And self-generation ultimately means firms depend on one fuel source (mostly diesel), which means sacrificing economies of scale, and becoming vulnerable to global price changes (Collier and Cust, 2015). This introduces instability in the prices consumers pay for goods, which is an eventuality that democratic governments, acting under electoral constraints, can ill afford.

Suppose we follow the line of reasoning that incumbents act according to their perception of credible threats and assume that in a dictatorship, the only threat to power is large scale protests. In that case, we can make the following argument: because non-democratic regimes don’t have to deal with electoral constraints, they prioritise the residential sector in urban areas because it poses the most significant political threat. Dictatorships neglect industry, because industry can generate its own electricity, if need be, and pass the cost down to the consumer.

2.3.5 Electrification and electricity subsidies

Democratic governments choose electrification policies that maximise their return on investment in terms of votes. How citizens cast their vote is a direct consequence of the effect of electrification on their wellbeing. Considering the literature discussed thus far, it might seem reasonable for democratic governments to implement large scale electrification projects in poor rural areas. Plus, tentatively, the associated benefits of electrification are numerous. For example, in Bangladesh and Vietnam, electrification positively affects income, school performance, and employability (Shahidur R Khandker, Barnes and Samad, 2012; Khandker, Barnes and Samad, 2013). The same is true for India (van de Walle *et al.*, 2017), where the effect is also positive on women. Electricity provision has a positive impact on literacy, income and health for women in urban slums in India (Parikh *et al.*, 2015) and has contributed to the decline in fertility rates in Indonesia and Cote d'Ivoire (Peters and Vance, 2011; Grimm, Sparrow and Tasciotti, 2015). There are, however, some mixed results from studies on African countries: positive effects on employment in South Africa (Dinkelman, 2011); positive effects on rural development in Kenya (Kirubi *et al.*, 2009); no significant effect on small enterprises in West Africa, Uganda and Benin (Neelsen and Peters, 2011; Peters, Vance and Harsdorff, 2011; Grimm, Hartwig and Lay, 2013). Similarly, in Rwanda, the Rwandan Electricity Access Role-Out Program significantly increased electricity connections but had no substantial effect on electricity uptake or income, health and education (Lenz *et al.*, 2017). Given these uncertainties and the costs associated with infrastructure investment, it is indeed possible for democratic governments to choose subsidies as a strategy to increase electricity consumption in the residential sector, as suggested by Brown and Mobarak (2009).

Yet, despite some evidence of the potential positive impacts of electrification, the adoption of electricity subsidies by democratic regimes is not an obvious choice because there are no guarantees that poor households will benefit the most.

Several studies have shown that electricity subsidies tend to benefit the highest income groups in developing countries. The wealthiest households receive between 3 and 6 times as much subsidies as the poorest households in Pakistan and Bangladesh (Trimble, Yoshida and Saqib, 2011; Ahmed, Trimble and Yoshida, 2013). Similar results were found for electricity subsidies in China and Mexico (Komives *et al.*, 2009; Wang and Zhang, 2016). The same is true in Sub-Saharan Africa. For example, poor households in Ghana and Burkina Faso receive less than 10% of subsidies, while poor households in Rwanda receive only 0.5% of total electricity subsidies (Banerjee *et al.*, 2008). In Zambia, the poorest 50% of households receive only 2% of total subsidies, and the bottom quintile receives only 1% (de la Fuente, Rosales and Jellema, 2017; Maboshe, Kabechani and Chelwa, 2019). Subsidies, consequently, would serve autocratic governments more. Since the middle to top income quintiles benefit from electricity subsidies and are more likely to reside in urban areas, authoritarian governments could adopt subsidy programs to provide cheaper electricity to urban residents without spending on infrastructure projects. For democratic governments, on the other hand, it could be challenging to ensure the benefits of subsidies serve their intended targets. Regardless of regime type, urban residents are the most likely beneficiaries of electricity subsidies. Therefore, an argument can be made that the prioritisation of electricity to the residential sector will be in the form of subsidies, not large infrastructure projects. Hence, residents get cheap – potentially unreliable – electricity in urban areas, where access to electricity is highest.

2.3.6 Infrastructure investment and regime type

A report by the World Bank on the state of Africa's infrastructure makes several significant claims. One of the findings is that most of the energy infrastructure in the continent is locally financed (Brew-Hammond, 2010; Foster and Briceno-Garmendia, 2010). More specifically, the overwhelming majority of energy infrastructure investment is funded through tax revenues and implemented within central government budgets. The projects are maintained using revenue generated through service provision and operated as state-owned enterprises (Foster and Briceno-Garmendia, 2010). Furthermore, most Sub-Saharan African countries spend between 6% and 12% of gross domestic product (GDP) annually on infrastructure: ICT, power, roads, water and sanitation (Briceño-Garmendia, Smits and Foster, 2009). While these figures seem high relative to more developed OECD countries, the absolute dollar values paint a clearer picture: most countries spend less than $50 per person and less than $600 million in total per year. This is mainly spent on services run by governments as state-owned enterprises.

Like most other public services, most of the electricity infrastructure in Sub-Saharan Africa is centralised and bundled. Governments have a monopoly over electricity supply and investment in electricity infrastructure. Sub-Saharan African countries face several barriers to a more efficient power sector, chief among which is institutional capacity. One way to increase efficiency is power sector reform. A recent study found that electricity sector reform in some Sub-Saharan African countries had a positive effect on the sector: reduced corruption and increased efficiency (Imam, Jamasb and Llorca, 2019). Lower corruption and increased efficiency are outcomes from which democratic governments, operating under electoral and budget constraints, would benefit. There is evidence that democratic governments in developing countries are more likely to adopt power sector reform (Urpelainen and Yang, 2019). This finding is intuitive. An increase in efficiency and decrease in corruption will lower the required inputs to achieve a certain level of output (Dal Bó and Rossi, 2007).

Hence, allowing private sector participation in the power sector frees up portions of the budget that can be spent elsewhere, such as health and education. This is especially attractive for democratic governments because, as we've established, the actual beneficiaries of electricity subsidies are the urban rich. (The reality, however, is that, even among more democratic developing countries, hybrid electricity markets are still dominant. And there is little evidence of the poor benefiting from liberalised electricity markets. There is evidence of the contrary: see, for example, Karekezi and Kimani (2002)). On the other hand, autocratic governments would not necessarily benefit from lower corruption in utilities and, hence, are unlikely to adopt electricity sector reforms.

Autocratic regimes are more inclined to support infrastructure investment. Large infrastructure projects present more opportunities for corruption and for authoritarian regimes to reward supporters. Electricity in most of Sub-Saharan Africa is a cash-intensive business. Most households and businesses pay for electricity using cash or bank transfers. Corruption in utilities could become entrenched by adopting seemingly progressive reform. For example, in Sudan, the unbundled electricity generation, transmission and distribution companies can be operated beyond the reach of government ministries (Imam, Jamasb and Llorca, 2019). Also, there's a tendency for aid money to be targeted at new construction (Briceño-Garmendia, Smits and Foster, 2009). Beyond the internal corruption of utilities, autocratic governments benefit from large scale construction projects (Collier and Cust, 2015). This means that it is in the interest of autocratic regimes to invest in large-scale infrastructure projects from time to time. And because electricity is a valuable, verifiable service (that can be used in pro-development rhetoric), it seems like an obvious choice for an autocratic government aiming to stay in power.

So, non-democratic regimes can occasionally spend on large scale electricity projects to satisfy growing urban needs and curb dissent. Non-democratic governments don't mind large scale infrastructure projects (when they can afford them) because the power sector is conducive to corruption. This also serves an autocratic regime's agenda of distribution of resources to supporters (assuming a considerable proportion of employees at State-Owned Enterprises are employed based on their support for the government, not their competence; see, for example, Mann (2014)).

2.3.7 Democracies vs autocracies in electrification

Politics plays a crucial role in the delivery of public services. The delivery of public services depends on institutional quality, government accountability and inclusiveness. There is, however, some suggestion that better institutions are not always the answer. The process of democratisation is not an obvious solution either. Electricity is commonly used as a political tool. Electricity provision can be manipulated to influence the outcome of elections. Governments acting under electoral constraints are keen to show their commitment to service provision to win votes.

The political drivers of electrification in developing countries are varied. Some of the motivations for electrification projects, like other development programs, stem from international funding and political support. There is, however, some evidence to suggest a positive relationship between institutional quality and electricity consumption. There is evidence that democracy is conducive to the provision and efficiency of public service provision in the literature. But there's also evidence that democracy incentivises politicians to act unfavourably and use public service provision as a political tool. The effect of politics, institutions and governance on energy access is complex, with no clear consensus in the literature.

Furthermore, unlike democracies, autocratic governments and their policies regarding public service provision are not constrained by electoral processes. If responding to the incentives they face, authoritarian governments are more likely to prioritise urban residents over industrial consumers. Democratic governments choose electrification policies that maximise their return on investment in terms of votes. The adoption of electricity subsidies is not an obvious choice because there are no guaranteed benefits to poor households, and neither are large scale infrastructure projects because of budget constraints. Like most other public services, most of the electricity infrastructure in Sub-Saharan Africa is centralised and bundled. Governments have a monopoly over electricity supply and investment in electricity infrastructure. Democratic governments are more likely to adopt power sector reform policies to reduce corruption and increase efficiency. Autocratic regimes are more inclined to support infrastructure investment. Large infrastructure projects present more opportunities for corruption and for authoritarian regimes to reward supporters.

Democratic governments prioritise rural electrification, while non-democratic governments, not constrained by votes, prioritise urban electricity access. Non-democratic governments can satisfy urban electricity needs through subsidies, a cheaper option than grid expansion. Non-democratic governments can, from time to time, afford large scale electrification projects that serve a dual purpose: provide electricity to urban residents and provide a mechanism through which the government can reward its supporters. So, if democratic governments act "non-democratically" and prioritise urban electrification, which will induce economic growth, rural electrification will eventually be achieved as a by-product of that growth. Expanding utilities to serve urban areas under a democratic regime is likely to be more efficient than a utility operating under a non-democratic authority because corruption decreases the efficiency of public utilities. Under the control of a democratic government, utilities will run more efficiently and play their role in powering (pun intended) economic growth.

The arguments made thus far suggest that because of autocratic governments' neglect of industry and inefficient electricity distribution, a growing urban population in countries with authoritarian governments concerned with short-term urban power provision will only hinder efforts towards universal electricity access. Urbanisation puts pressure on urban electricity access. Urban areas are the centre of economic activity. Democratic governments, from time to time, should act non-democratically to deal with the inevitable surge in urban electricity demand. The caveat here is that democratic governments working in favour of urban electricity demand should consider the needs of all urban residents, not just the ones that pose a political threat, poor households and slums included.

2.4 Electricity access for low-income households

The literature discussed in the previous section points to the important role institutions play in public service provision in general, and electricity in particular. There is evidence to suggest that different regime types provide electricity in different ways depending on the incentives they face. For example, more democratic regimes are constrained by being voted out of office and more autocratic regimes are constrained by elite popular discontent. This means that, the governance structures and institutional quality in a country can determine whether and how low-income households, in both rural and urban areas, get access to electricity.

In 2008, GNESD reported that urban energy access is hindered by several factors: no strategic and long-term planning; structure of settlements limiting access to modern fuels; high upfront costs of clean technologies; limited institutional support and engagement; ineffective subsidies (GNESD, 2008). Most, if not all, of these problems, still exist. Today, over 1 billion people don't have access to electricity, and almost 2 billion people don't have access to clean, modern cooking fuels (IEA IRENA UNSD World Bank WHO, 2022). In developing countries, most people without access to electricity reside in the rural areas. However, the situation is not perfect in urban areas. Newly urbanised populations face similar problems, fleeing war, famine, and desolate landscapes. The promise of opportunity, stability and quality of life in the urban centres of the developing world has induced unprecedented urbanisation. More than half of the world's population lives in urban areas. The increasing rate of urbanisation in developing countries has resulted in many urban-poor not having access to modern energy services. Rural energy access is a regular feature in government energy policies and research literature (see, for example, Davis, 1998; Cecelski, 2000; Sebitosi and Pillay, 2005; Kanagawa and Nakata, 2006, 2008; Nguyen, 2007; Kankam and Boon, 2009; Mustonen, 2010; Pereira, Freitas and da Silva, 2010; Bernard, 2012; Srivastava et al., 2012; Grogan and Sadanand, 2013)). Apart from occasional reports (GNESD, 2008; ESMAP, 2011; R Singh *et al.*, 2015), in most developing countries, the needs of the urban poor in terms of access to modern energy have not garnered as much attention (R Singh *et al.*, 2015).

2.4.1 Factors affecting energy access

There are plenty of factors that influence a household's use of electricity. For example, Rahut et al. (2017) found that demographic characteristics, household wealth, proximity to markets and distance from urban centres are significant factors in determining households' electricity use for lighting and cooking in Ethiopia, Malawi, Tanzania and Uganda. The authors claim this result is evidence of a "ladder within a ladder." Basically, beyond income, other factors determine a household's electricity use. This conclusion is in line with criticisms of the energy ladder hypothesis (see, for example, Masera and Navia, 1997; Masera, Saatkamp and Kammen, 2000; Hiemstra-van der Horst and Hovorka, 2008; Mekonnen and Kohlin, 2009; Nansaior et al., 2011; Sovacool, 2012; van der

Kroon, Brouwer and van Beukering, 2013; Yonemitsu et al., 2014; Alem et al., 2015)). The general relationship between the urban slum population and energy consumption in developing countries is negative. The increase in the urban poor population in slums doesn't induce growth in energy consumption (Jorgenson, Rice and Clark, 2010). Energy consumption, however, has a positive association with the total urban population. This point highlights the problem of energy access in urban slums and the difference in energy consumption between the urban poor and the rest of the urban population.

Access to energy services in urban slums depends on many factors. One major factor is policy. For example, until 2008, the Indian government did not recognise clean energy service as an urban service, and as a result, energy access was not included in infrastructure and urban development programmes (Dhingra *et al.*, 2008). One major drawback of this outcome is that other potentially beneficial policies, such as energy subsidies to the poor, do not reach their intended targets. The significance of policy is evident in the level of access to services in slums in different countries with different approaches. A study of poverty and living conditions of slum residents in Nairobi and Dakar finds that slum residents in Nairobi, on average, earn more, are better educated, and are better employed than slums residents in Dakar. However, slum residents in Dakar feel safer, are more likely to own their homes, have better infrastructure, are more likely to have permanent walls, and have much better access to water, electricity, and drainage services (Gulyani, Bassett and Talukdar, 2014). This can be attributed to more responsive and active city-level administration. These findings point to the importance of policy in providing public services to urban slum residents.

One significant demand-side barrier to modern energy access in urban slums is affordability. Poor households, on average, pay a larger portion of their income for low-quality energy services than higher-income households do for better energy services (Scott, Dunn and Sugden, 2003). For example, in the 1990s in Dar es Salaam, Tanzania, the cost of electricity per megajoule of useful energy was half that of LPG and a third of the cost of kerosene (Foster, 2000). This is one of the main motivations for better government policy. In South Africa, where slum electrification is generally very high compared to other Sub-Saharan African countries, many slum dwellers can't afford to use electricity despite having a connection (Visagie, 2008).

As a result, some households resort to extension cords and are, therefore, subjected to the associated uncertainties of unreliable supply, the danger of electrocution and unpredictable rates. In slums in Mumbai, India, Mimmi (2014), using households' willingness to pay, finds that affordability is a significant barrier to regulating informal electricity supply. Most slum residents find the upfront investment and the eventual consumption fees too much to bear. From an energy poverty perspective, there is evidence of the importance of policy in providing energy access. Using data from India and employing a definition of energy poverty as "the threshold point beyond which energy consumption begins to rise with increasing household income," Shahidur R. Khandker, Barnes and Samad (2012) find that 57% of rural households are energy poor, but only 22% are income poor. In urban areas, 28% of households are energy poor, but only 20% are income poor. This suggests that having a higher income does not necessarily protect from energy poverty and doesn't guarantee energy access. And that being income poor in an urban area increases your chance of being energy poor. This, in turn, highlights the importance of energy policy in expanding modern energy services to rural and urban poor areas.

Another significant barrier to energy access in urban slums, discussed in Section 2.3, is institutional. For example, in India, slums are more likely to have access if they're situated in a state with a leftist ruling party (Aklin *et al.*, 2015). In Dhaka, Bangladesh, city-level energy policies are designed without considering slum development (Lipu, Jamal and Miah, 2013). In South Africa, Runsten, Nerini and Tait (2018) have identified three significant barriers to energy access for urban settlements: political will, policy and subsidy allocation, all of which are centred around government energy policy. The same is true in other Sub-Saharan African cities. In peri-urban areas of Dakar, Senegal, Fall et al. (2008) have identified the following barriers to modern energy access: an institutional gap in understanding how peri-urban areas function; the lack of a dedicated and informed energy policy; land tenancy; and an exclusionary policy for households far from the national grid. In Kenya, de Bercegol and Monstadt (2018) consider the lack of political inclusion of slum dwellers as a major impediment to the success of Kenya's new Kenya Slum Electrification Project.

2.4.2 Consequences of poor access

The types of fuels consumed by poor households and households in urban slums are different in each country, but a discernible pattern exists. In Kibera, Kenya's most populous urban slum, most households consume kerosene for lighting and cooking. Very few households consume biomass fuels, such as charcoal or LPG (Karekezi, Kimani and Onguru, 2008). This is an exciting finding, and a perfect illustration of the difference between urban and rural energy consumption, especially among poor households. Dependence on kerosene for both cooking and lighting requires consistent supply. This can only be guaranteed through an efficient supply chain and a functioning market, which is much more likely to exist in urban than rural areas (Visagie, 2008).

Similarly, kerosene is a popular fuel among urban poor households in Buenos Aires (Bravo, Kozulj and Landaveri, 2008). The same is true for Bangkok, Delhi and Dhaka (Dhingra *et al.*, 2008; Shrestha *et al.*, 2008; Lipu, Jamal and Miah, 2013). The characteristics of a popular fuel in urban slums are centred around affordability and availability.

One consequence of poor access to electricity in urban slums is electricity theft. There is extensive literature on electricity theft in developing countries (see, for example, Mimmi and Ecer, 2010; Depuru, Wang and Devabhaktuni, 2011; Winther, 2012; Never, 2015; Yurtseven, 2015; Gaur and Gupta, 2016). Electricity theft is most prevalent among low-income households. Other determinants of the incidence of electricity theft include below-standard energy services and the operation of informal businesses from homes (Mimmi and Ecer, 2010). The first factor highlights the available options to urban slum dwellers who have a need, and potentially the ability to pay, for electricity services. The second factor gives credence to the importance of electricity for economic activity.

As one might expect, factors such as corruption, electricity bill collection and private generation are also significant in determining the levels of electricity theft (Gaur and Gupta, 2016). All these factors can be tackled by more targeted and better-enforced government policy: renewable energy subsidies to increase private generation; more stringent bill collection measures; slum electrification policy to serve those willing and able to pay; discounts on installation and special tariffs to home-run businesses. Electricity theft, although illegal, is one way for households to get access to affordable electricity. One other option is getting connected through a neighbour. For example, all homes in urban slums in Thailand have access to electricity. Still, some studies show that not all slum residents with electricity connections get their electricity from the national grid. A significant number of households, especially in Bangkok, buy electricity from their neighbours every month (Shrestha *et al.*, 2008).

In many ways, the availability of an electricity supply doesn't imply access, and access doesn't imply use. If, for example, a house is located within proximity of the grid, it is not guaranteed a connection because connections require capital. Should the household then come up with the money needed for a connection and install a meter, this does not guarantee consistent use of electricity for several possible reasons: the electricity tariffs could be too high, regular power outages, or voltage fluctuations. Essentially, electricity is most useful if it's available, affordable and reliable (Reddy, 2015). Hence the need for policy.

2.4.3 Policies and energy access for low-income households

Several examples of positive policy programmes increase access to modern fuels for low-income households. For instance, in Brazil, LPG was introduced in the late 1930s as a viable cooking fuel to decrease the use of traditional fuelwood. Similarly, the "Light for all" program, introduced in the 1990s, managed to extend the national electricity grid to over 10 million (Coelho and Goldemberg, 2013). Both programs, of course, were implemented in an environment and during a time that was conducive to their success. More specifically, an electrification program in Sao Paolo, Brazil, successfully provided electricity connections to shacks in Favelas (Patterson, Eberhard and Suarez, 2002). The total cost of the connection was subsidised, and the electricity, provided at a subsidised flat rate, was paid for monthly. The results were encouraging. Electric lighting made cleaning the house easier, eliminated indoor pollution and made taking care of children less stressful because of a reduced risk of fire accidents. The most significant consequence is that an electricity connection gave residents access to credit systems through their electricity bills, which contained all relevant personal information. There are examples of the success of slum electrification policies in East Asia. In Thailand, 100 % of slum residents have electricity, and most households use LPG for cooking. The high access to modern energy in slums is mainly due to a successful electrification program, house registration policies, price subsidies and low monthly electricity service charges for poor households (Shrestha *et al.*, 2008).

Equally, there are examples of ill-conceived policy programmes. In Dhaka, Bangladesh, almost all households in slum areas have access to electricity, but not all have individual meters. The local utility has set up pole meters that serve several homes and operates on a credit basis. The pole meter and electricity distribution are supervised by a community leader who oversees pricing. This doesn't usually work out in the residents' favour. This system, however, is seen as "better than nothing," as most households, even if they can afford the high upfront cost, wouldn't be able to get an individual meter because they would invariably lack the required legal documents. As a result, electricity connections are unreliable, more expensive and unsafe. For Dhaka, Lipu, Jamal and Miah (2013) have identified several barriers to electricity uptake in urban slums. An energy policy barrier exists in that government energy policy, effective since 1996, has not been tailored to cater to the urban poor. Government housing policies have failed to provide the urban poor with legal settlements, and as a result, they cannot get a metered electricity connection legally. In addition, there are no institutions tasked with taking care of or monitoring and evaluating electricity services to the urban poor. There are also losses in transmission and distribution associated with outdated infrastructure.

Conducive government policies must support efforts to provide modern energy services to urban slum residents. Several studies have emphasised the importance of policy in delivering reliable and affordable energy services in urban slums (see, for example, Lipu, Jamal and Miah, 2013; Mimmi, 2014; Lee et al., 2016; Runsten, Nerini and Tait, 2018)). For example, the failure of electrification agendas in Ghana in the past couple of decades can be attributed to a lack of coherent national policies, no priority for the urban poor population and no clear strategies or financing mechanisms (Kemausuor *et al.*, 2011). Some studies argue for subsidies to increase better energy services for underserved areas (Lee *et al.*, 2016). Another common policy criticism is that government departments concerned with energy service delivery and slum development are isolated from one another (see, for example, Lipu, Jamal and Miah (2013) for Bangladesh; Runsten, Nerini and Tait (2018) for South Africa).

It is also evident from the literature that energy access is not only dependent on electrification policies but also on housing policy, which determines the legal status of households in slums; infrastructure policies, which determine infrastructure development areas; and development policies, which target the urban poor (see, for example, Visagie (2008) for South Africa; Fall et al. (2008) for Senegal; Lipu, Jamal and Miah (2013) for Bangladesh; Mimmi (2014) for India).

2.5 Research gaps

The econometrics-focused literature on the relationship between urbanisation and energy consumption is rich in its use of different estimation techniques, studying different regions and using a variety of dependent variables (for example, electricity consumption, energy consumption, road energy use, energy intensity, etc.). There is, however, a lack of contextual justification for the results of the estimation. The general methodology in some of the studies highlights the use of different urbanisation variables to gauge the impact of urbanisation on energy consumption without considering the country context. For example, one implicit assumption in studies on countries with different levels of development is that rural-urban migrants have the same consumption habits across countries. Furthermore, very few studies look at the effect of urbanisation on energy consumption in Sub-Saharan Africa. This, understandably, might be due to data constraints. Finally, no studies look at the impact of urbanisation on sectoral energy consumption or energy use by type. For example, most studies use either per capita energy consumption or total energy consumption instead of industrial and residential energy consumption or electricity and biomass energy consumption. This thesis, firstly, adds to the literature on urbanisation and energy access by estimating the effect of urbanisation in Sub-Saharan African countries on total energy consumption and electricity consumption, by answering the research question: what is the effect of urbanisation on energy and electricity consumption in Sub-Saharan Africa?

The literature on the institutional effects on service provision, including electricity provision, is extensive. The merits of democratic institutions on rural electricity access are covered in length. There are some very insightful findings regarding how the democratic process affects access to services. For example, how politicians actively choose for utilities to incur losses to win elections. The studies have used econometric tools, such as multinomial logit models, to estimate specific effects of institutional qualities on energy use. However, among the studies that look at the institutional aspects of energy provision and electricity access in developing countries, no studies specifically look at the institutional aspects of urban energy access in Sub-Saharan Africa. Therefore, secondly, this thesis attempts to provide insights into how autocratic governments will deal with the demographic changes happening in Sub-Saharan Africa regarding energy provision by answering the research question: what is the relationship between governance and urban electricity access? Thus far, the argument suggests that because of authoritarian governments' neglect of industry and inefficient electricity distribution, a growing urban population in countries with authoritarian governments concerned with short-term urban power provision will only hinder efforts towards universal electricity access. And that democratic governments, from time to time, should act non-democratically to deal with the inevitable surge in urban electricity demand.

Most studies looking at policy in urban areas do qualitative analyses. There is a gap in the literature for a quantitative examination of the effect of policy on electricity access. The impact of policy on energy access and use in urban slums is easily verifiable (see (Coelho and Goldemberg, 2013) for electricity and LPG in Brazil; see (Patterson, Eberhard and Suarez, 2002), for electricity in Favelas in Sao Paolo; see, (Shrestha *et al.*, 2008), for urban slums in Thailand). And most studies looking at the institutional aspects of energy access have conducted macro-level studies using econometric analysis to quantify the effect of institutions on energy access. Hence, there is a gap in the literature for using household-level data to gauge the impact of government policy on energy access. Hence, thirdly, this thesis uses household energy consumption data from Rwanda to estimate the impact of policy on electricity access by comparing electricity access in rural households to households in urban slums and households in rural resettlement areas. This is achieved by answering the research question: what is the effect of government policy on access to electricity for poor households?

3 Chapter 3: Urbanisation and energy consumption

3.1 Framing

The relationship between urbanisation and energy consumption has been studied extensively, but very few studies look at Sub-Saharan Africa. The literature is reviewed in more detail in Section 2.2. In most studies, there was general agreement that urbanisation increases energy consumption. The justification being that when people move from rural to urban areas, they adopt more energy-intensive lifestyles and engage in energy-intensive economic activities. Given the different regions covered by the literature and the different econometric estimation techniques used, the review showed that similar estimation methods produced different results for different regions and different estimation methods produced similar results for the same region.

This was evident in the several studies that look at Malaysia and find similar results. Within the existing literature, many studies attempt to estimate the relationship between urbanisation and energy consumption in China. The motivation for this is China's recent economic growth and rapid urbanisation. Understandably, regional, and provincial studies on China find variation due to the level of development. In addition to variations across regions and levels of development within a country, there is also evidence of variation due to levels of development across countries. The literature inadvertently converges to a significant argument: urbanisation has little or no effect on energy consumption in low-income countries. Alas, not all the studies can attribute their results to differences in income, development, or level of urbanisation. Some findings were attributed to the data, choice of explanatory variables, or the model used.

Despite the breadth of the literature, perhaps due to data limitations, studies on the relationship between urbanisation and energy consumption in Sub-Saharan Africa are limited. Understandably, it can be assumed that an increase in the urban population would cause an increase in both total energy and electricity consumption. Figure *3.1* shows that Sub-Saharan African countries with larger urban populations tend to have higher levels of energy and electricity consumption. But as we have established in Section 2.2, context matters. The availability of certain types of energy, and whether people can access it and are able to afford it makes a difference on the overarching impact of urbanisation on energy use.

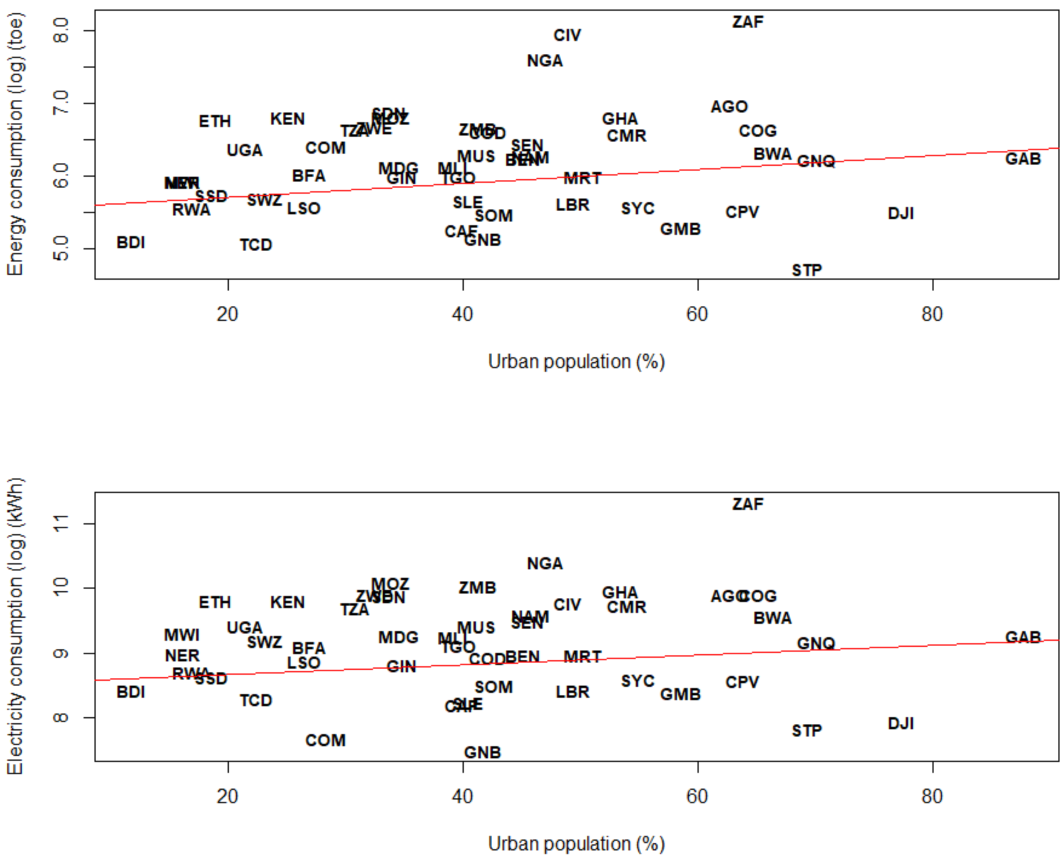

Figure 3.1 - Total energy consumption and electricity consumptions vs urban population in Sub-Saharan Africa (Data is for 2014) (World Bank, 2020a).

3.2 Research proposition

This chapter focuses on research question 1: What is the effect of urbanisation, and its significance, on energy consumption in Sub-Saharan Africa?

Hypothesis 1: Urbanisation has a positive effect on total energy consumption in Sub-Saharan Africa. As more people move to urban areas, increases in income are expected to translate to increases in the use of both modern energy and technologies and the use of less efficient traditional fuels. Controlling for total population, this should increase total consumption.

Hypothesis 2: Urbanisation has no effect on total electricity consumption. Rural-urban migrants are relatively poor and are, therefore, more likely to reside in urban areas where access to electricity is limited and are less likely to be able to afford both the upfront cost of a connection to the grid and regular consumption of electricity even if it's available. Furthermore, the likelihood of having access to electricity for rural-urban migrants is further reduced by the fact that grid expansion has not kept up with urban population growth.

3.3 Methodology: Estimation and data

This study uses panel data (see Section 3.3.2) to estimate the effect of urbanisation on energy consumption while controlling for demographic, economic and political variables. Using country-level data, the estimation exercise aims to find the effect of urbanisation on total energy consumption and electricity consumption.

3.3.1 Model estimation

To study the impact of urbanisation on energy consumption, a static and dynamic model are estimated using the panel dataset with energy type (total energy consumption or electricity consumption) as the dependent variable and total urban population as the main explanatory variable. A VAR model is also estimated for each country separately.

3.3.1.1 Static model

This study is interested in the effect of urbanisation on energy consumption. To estimate this effect the model controls for other demographic, economic and political factors. The model used for the estimation is the following:

$$y_{it} = \beta_0 + \beta_1 urb_{it} + \boldsymbol{X}_{it}\beta + v_t + \alpha_i + u_{it} \tag{3.1}$$

where y_{it} is the dependent variable (the type of energy consumed, depending on the model in question), β_0 is the intercept, urb_{it} is the urbanisation variable, $\boldsymbol{X}_{it}$ is a K-dimensional vector of explanatory variables, β is a (K × 1) vector of slopes, v_t is an error term of factors that are solely time dependent, α_i is an error term of factors that are solely country dependent (don't vary across time), and u_{it} is an error term of idiosyncratic factors that influence energy consumption in country i at time t.

First, to test for stationarity, an Augmented Dickey-Fuller test is conducted to check for stochastic trends. The null hypothesis is that the series has a unit root (non-stationary). If a unit root is present, we estimate a first differences model. The results of the Augmented Dickey-Fuller test are presented in Table *8.3* in Appendix B.

In the absence of a unit root, fixed effects and random effects models are estimated for the two dependent variables. The following fixed effects model is estimated

$$log(y)_{it} = \beta_0 + \beta_1 log(urb)_{it} + \boldsymbol{X}_{it}\beta + e_{it}$$

(3.2)

where y is the dependent variable, urb_{it} is the urbanisation variable, $\boldsymbol{X}_{it}$ is a K-dimensional vector of explanatory variables, β is a (K × 1) vector of slopes, and e_{it} is an error term of idiosyncratic factors that influence energy consumption in country i at time t. Then, the following random effects model is estimated

$$log(y)_{it} = \overline{\beta_0} + \beta_1 log(urb)_{it} + \boldsymbol{X'}_{it}\beta + v_{it}$$

(3.3)

where $\overline{\beta_1}$ is a population average for the intercept, and the error term v_{it} incorporates both individual and original regression errors.

Then a Hausmann test is conducted to determine which model is more consistent. The Hausmann test tests whether the unique errors (u_{it}) are correlated with the regressors, where the null hypothesis is that there is no correlation between the two and random effects is the preferred model (Wooldridge, 2002). The results of the Hausmann test are presented in Table *8.4* in Appendix B.

If fixed effects is the most consistent model, the Lagrange Multiplier (Bresuch-Pagan) test is used to test for time-fixed effects. If a random effects model is more consistent, the Lagrange Multiplier test is conduced to test for random effects (to determine between a random effects model and a pooled model). The results of Lagrange Multiplier test are presented in Table *8.5* in Appendix B.

Finally, a test for autocorrelation of errors is conducted. This is done by obtaining the residuals from the estimated model and estimating the following auxiliary regression using OLS

$$e_{it} = \rho e_{i,t-1} + \eta_{it} \tag{3.4}$$

where ρ is the autocorrelation coefficient. If ρ is statistically significant, the null hypothesis of no autocorrelation is rejected. The results of the estimation of Equation (3.4) are presented in Table *8.7* in Appendix B.

As a robustness check, three general feasible generalised least squares (GLS) models are estimated, one unrestricted with individual effects, one unrestricted with time effects, and one with fixed effects. For the unrestricted model, an OLS model is first estimated, then an error covariance matrix is estimated using the residuals of the OLS model (Wooldridge, 2002).[5] The model is estimated with time effects, therefore accounting for arbitrary cross-sectional correlation. For the fixed effects GLS (FEGLS), a within model is estimated first. Furthermore, a fixed effects variable coefficients model (VCM) with individual effects is estimated. The coefficients are assumed fixed, so a separate model is estimated for each country (the results of the VCM are reported in Appendix B).

The main dependent variables are total energy consumption and electricity consumption. Total energy consumption represents a country's consumption of all types of energy. Electricity consumption represents a country's total electricity consumption from all generation sources. The key explanatory variable is the urbanisation variable represented by total urban population. Urban population represents the number of people living in urban areas. The main goal of the

[5] The estimated error covariance matrix is $\hat{V} = I_n \otimes \widehat{\Omega}$, where $\widehat{\Omega} = \sum_{i=1}^{n} \frac{\hat{u}_{it}\hat{u}_{it}^T}{n}$.

estimation exercise is to determine the impact of an increase in the urban population on total energy consumption and electricity consumption.

Following past literature, economic and demographic controls are included. GDP is included as a control for the level of economic development and total population as a control for the effect of population on energy consumption (population is a major factor in large scale consumption and varies across countries (York, 2007b)). Industry value added is included as a control for technological development, as in much of the literature. Finally, the estimation includes a democracy variable, a hybrid indicator used as a proxy for quality of governance.

3.3.1.2 VAR model

An augmented Dickey-Fuller test is performed on the time series of urban population and energy type for each country to test for stationarity. The null hypothesis of the test is that the time series is non-stationary. Understandably, for all the countries in the dataset, the time series have a time-dependent structure and do not have constant variance over time (fail to reject the null hypothesis). This makes sense because of the rate of population increase and subsequent consumption habits.

To decide between a VAR model and vector error correction model (VECM), a Johansen test is performed to test for cointegration between the urban population and energy consumption time series. The test checks the rank of the eigenvalue decomposed coefficient matrix of first lags. The null hypothesis is that the rank of the matrix, $r = 0$, which means there is no cointegration between the pair of time series. For robustness, for each pair of time series, two Johansen tests are carried out, one using a trace test statistic and the other a maximum eigenvalue test statistic. Because the observations are annual, a lag of 1 is specified for the VAR model. For all the countries in the sample, the test fails to reject the null hypothesis of no cointegration.

A VAR model of energy consumption and urbanisation is estimated for each country

$$log(y)_t = \beta_{10} + \beta_{11}log(y)_{t-1} + \beta_{12}log(urb)_{t-1} + u_{1t} \tag{3.5}$$

$$log(urb)_t = \beta_{20} + \beta_{21}log(urb)_{t-1} + \beta_{22}log(y)_{t-1} + u_{2t} \tag{3.6}$$

Furthermore, a Granger-causality test is performed for each country.[6] The null hypothesis of the test is that urbanisation does not Granger-cause energy consumption (and vice versa). First, the test is performed to determine whether urbanisation Granger-causes energy consumption. Then reverse causation is tested by performing the Granger-causality test in reverse. The test reports an F statistic with a corresponding p-value. The null hypothesis of no causality is rejected when the p-value is below a certain significance level. Only cases where the null hypothesis is rejected are reported (the results of the VAR estimation are reported in Appendix B).

3.3.1.3 Dynamic model

The generalised method of moments (GMM) estimator is used to estimate a dynamic model, where lags of the dependent variable are included in the right-hand side of the estimation equation

$$log(y)_{it} = \phi log(y)_{i,t-1} + \beta_1 log(urb)_{it} + \boldsymbol{X}_{it}\beta + \eta_i + \varepsilon_{it} \tag{3.7}$$

where ϕ is the coefficient of the lagged dependent variable.[7] GMM estimation, a dynamic panel data estimator, uses moment conditions, functions of the parameters of the model, as instruments. Given that that both N and T are large

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[6] It should be noted that the ability of this test to infer a causal relationship is limited. What the result of the test more accurately implies is that past values of x improve the prediction of the values of y, and vice versa.

[7] The difference GMM estimator transforms the same initial model through first differencing, removing the fixed effect. The transformed model looks like this: $\Delta\log(y)_{it} = \phi\Delta\log(y)_{i,t-1} + \Delta\boldsymbol{X}_{it}\beta + \Delta\varepsilon_{it}$.

in the dataset, OLS based methods suffer from Nickell bias (Nickell, 1981), which is persistent as N increases. Unobserved effects within countries arise in the error term, and, therefore, the dependent variable and its lag are correlated with the error term. This, by definition, violates the assumptions of a random effects model. The static fixed effects estimation doesn't work either because the time-demeaned error term would be correlated with the time-demeaned lag of the dependent variable. Moreover, the fixed effects estimator in a dynamic setting experiences first order serial correlation and bias, which increase with the autoregressive parameter, ϕ. The GMM estimator controls for endogeneity (correlation between the explanatory variable and the error term), omitted variable bias and unobserved panel heterogeneity.

There have been several developments made to GMM estimators, first popularised by Hansen (1982). There are two main GMM estimators: the difference GMM estimator (Arellano and Bond, 1991) and system GMM estimator (Blundell and Bond, 1998). The first estimator corrects for endogeneity by taking first differences to remove individual effects and uses lags of the dependent variable as instruments (Arellano and Bond, 1991).[8] One major drawback is that the first difference transformation decreases the number of observations, which is particularly problematic in unbalanced panels. The system GMM estimator uses additional moment conditions based on equations in levels and corrects endogeneity by introducing more instruments (in levels) to improve estimation efficiency and transforms the instruments to make them uncorrelated with the fixed effects (Blundell and Bond, 1998). Instead of first differencing, system GMM uses orthogonal deviations: subtracts the average of all future observations of the variable, therefore, reducing data loss.

Due to the presence of heteroskedasticity and serial correlation, a two-step system GMM estimator is used. In the first step, a sub-optimal weighting matrix is used to minimise the simple sum of squared errors in the moments to provide

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[8] For example, if a panel AR(1) model $y_{it} = \alpha y_{i,t-1} + u_{it}$ first differenced to remove individual effects looks like this: $y_{it} - y_{i,t-1} = \alpha\left(y_{i,t-1} - y_{i,t-2}\right) + \left(v_{it} - v_{i,t-1}\right)$. For t = 4, we have $y_{i4} - y_{i3} = \alpha(y_{i3} - y_{i2}) + (v_{i4} - v_{i3})$, in which case y_{i2} can be used as an instrument because it is not correlated with $(v_{i4} - v_{i3})$.

a preliminary estimate of the desired parameter. This parameter is then used to estimate an optimal weighting matrix, consequently used to provide a more asymptotically efficient estimate of the parameter.[9]

However, the two-step estimator is downward biased in small samples (Windmeijer, 2005). To address the issue of downward bias, Windmeijer corrected standard errors are used. The Hansen test for overidentification is used to test the model's specified restrictions, which is more suitable than a Sargan test for two-step estimation. The test also reports on the model's robustness.

3.3.2 Data

The data used in this study is obtained from several sources and spans the period 1980 to 2014[10]. Total energy consumption and electricity consumption is obtained from IEA's Energy Statistics Database. Urban population, GDP, total population, and industry value added are from the World Bank's World Development Indicators' database. The democracy indicator is calculated using data from Freedom House and Polity IV databases. The dataset is an unbalanced panel of 44 Sub-Saharan African countries. The average number of observations per group is 30. All variables, except the democracy indicator, are expressed in logarithm to the base 10 so that the coefficients of the estimated models can be interpreted as elasticities.

The original dependent variables, total energy consumption and electricity consumption, are measured in tonnes of oil equivalent (toe) and kilowatt hours (kWh), respectively. Urban population is the number of people living in urban areas, GDP and industry value added are measured in current US Dollars, and total population is the total number of people in the country. The democracy indicator is a hybrid of three indicators from two databases: Freedom House's political rights and civil liberties indicators, and Polity IV's democracy indicator.

[9] This process could be continued for more iterations, but a two-step estimator is usually sufficient.

[10] The dataset was limited to 2014 because of missing values for the different variables used in the model beyond that year, especially for low-income countries, such as Niger, Malawi and Burkina Faso.

The first two rate countries on a scale of 1 to 7, where 1 is best and 7 is worst. An average of the two is taken as the Freedom House indicator. The Polity IV democracy indicator uses an 11-point scale, between 0 and 10, as a measure of a country's institutionalised democracy. The Freedom House and Polity IV democracy indicators are normalised to a value between 0 and 1. The democracy indicator used in the estimation is an average of the two normalised indicators.

Table *3.1* presents the summary statistics for all the variables used in the estimation.

Table 3.1 - Summary statistics.

Descriptive statistics					
Statistic	N	Mean	St. Dev.	Min	Max
Total energy consumption (log)	1,363	5.9	0.7	4.2	8.2
Electricity consumption (log)	1,353	8.9	0.8	6.9	11.3
Urban population (log)	1,363	6.2	0.7	4.5	7.9
GDP (log)	1,363	9.6	0.7	8.0	11.7
Population (log)	1,363	6.8	0.7	4.8	8.2
Industry value added (log)	1,363	9.0	0.7	7.3	11.1
Governance	1,363	0.5	0.2	0.0	0.8

The estimation exercise does not account for energy prices for several reasons. First, for most of the countries in the sample there is insufficient data on local energy prices, especially in rural areas. Second, a significant proportion of energy in Sub-Saharan Africa is consumed outside official market channels. The energy mixes over the timeframe considered for most of countries in the sample (except for South Africa) are dominated by biomass. Apart from charcoal in urban areas, most traditional forms of biomass are consumed through collection or through informal means. Kerosene, the preferred fuel for lighting for households without access to electricity, is often purchased at a significantly higher price in rural areas relative to urban areas. For example, in Ghana in 2011, the median price per litre for kerosene in rural areas was 170% higher than in urban areas (Tracy and Jacobson, 2012). Finally, due to data limitations, the studies that use energy prices as an explanatory variable tend to use global crude oil prices. Over the timeframe considered, most Sub-Saharan African governments had subsidy regimes in place for electricity at different points in time for different reasons. Moreover, electricity from hydroelectric sources is, on average, 20% of total electricity production in Sub-Saharan Africa, and accounts for more than 90% in some countries (World Bank, 2020a). Therefore, global crude oil prices would not accurately reflect local prices for electricity.

3.4 Results

Table 3.2 presents the results of estimating the static model as per Equation (3.1). Columns (1) to (3) present the estimation results for total energy consumption as the dependent variable using pooled OLS (POLS), fixed effects (FE), and fixed effects instrumental variable (FE-IV) methods, respectively. Columns (4) to (6) do the same for electricity consumption as the dependent variable. As a robustness, Table 3.3 presents the results of estimating the same static model using general feasible generalised least squares estimation. FGLS assumes every group has an identical error covariance structure and is therefore inefficient in the presence of heteroskedasticity across groups. Understandably, the FGLS estimations overstate the statistical significance of the estimated coefficients because as the number of time periods increases the standard errors are biased downwards.

The magnitude and significance of the urbanisation variable in Table 3.2 is consistent for the different estimation techniques. The urbanisation variable has no significant effect on electricity consumption. GDP has a positive and significant effect on total energy consumption but only for the FE and FE-IV estimations and has no statistically significant effect on electricity consumption. Total population has a negative and statistically significant effect on total energy consumption but no significant effect on electricity consumption. Understandably, industry value added has a significant, positive impact on electricity consumption. An interesting outcome from the results of the estimation is the positive and significant impact of democracy on electricity consumption.[11] This result is explored further in Section 4.

[11] The democracy variable is a normalised hybrid of two democracy indicators, Freedom House and Polity IV. Therefore, it makes little sense to interpret its magnitude. For example, interpreting the coefficient of the FE model would lead to the nonsensical conclusion that a 1% increase in democracy increases electricity consumption by 0.367%.

Initial results of the empirical exercise in this chapter were published in Ali (2021) using data from the World Bank for the period 1980 to 2014 (except electricity access, which covers the period 1991 to 2014). The empirical exercise of Ali (2021) is based on two hypotheses. The first hypothesis is similar to Hypothesis 1 presented in Section 3.2. The second hypothesis differs from Hypothesis 2 in Section 3.2 in that urbanisation is expected to have “a small positive effect on total electricity consumption” (Ali, 2021, p. 4), whereas Hypothesis 2 in Section 3.2 posits that urbanisation should have no effect on total electricity consumption. Hypothesis 2 in this chapter is a refined version of the second hypothesis in Ali (2021) resulting from a broader exploration of the literature on urban electricity consumption, affordability of electricity and access in urban-poor areas. The literature reveals that, while access is higher in urban areas, electricity connection fees and consumption tariffs are a barrier for a large number of urban residents.

Ali (2021) presents the findings of a fixed effects estimation similar to Equation (3.2) for the two dependent variables: total energy consumption and total electricity consumption. The estimation includes additional control variables for the two estimation exercises. For the model which estimates the impact of urbanisation on total energy consumption, additional controls include resource rents, gross capital formation and exports. For the model which estimates the impact of urbanisation on total electricity consumption, additional controls include electricity access and exports. The fixed-effects estimation in this chapter does not control for resource rents, gross capital formation, exports or electricity access, in order to avoid data loss (data on resource rents, gross capital formation and electricity access is limited for some of the countries in the sample). Moreover, Ali (2021) estimates three additional models for each dependent variable grouping countries by income: low-income, lower-middle income and middle-income. This significantly reduces the number of observations per model, especially for the models estimating the impact of urbanisation on electricity consumption because of the limited time frame for data on electricity access.

The estimation results in Ali (2021) are similar to those in Table 3.2, where the effect of urbanisation on energy consumption is positive and significant. And the effect of urbanisation on electricity consumption is not statistically significant for both empirical exercises, but negative in Ali (2021). The difference is likely due to the smaller sample size in Ali (2021) covering the period 1991 to 2014 due to lack of data on electricity access. During this period, the increases in the rate of urbanisation, following poor economic performance in the 1980s and 1990s in Sub-Saharan Africa, far outweighed the rate of increase in electricity access. The results are also similar for governance: the effect of governance on energy consumption is negative and not significant for both sets of results and positive and significant on electricity consumption for both sets of results. Although, in Ali (2021), the governance coefficient is significantly smaller. This is also likely due to the smaller sample used in the analysis, where there are smaller variations in quality of governance within the timeframe covered by the data.

Table 3.2 - Results of estimating the static model.

	Dependent variable:					
	Total energy consumption			Electricity consumption		
	POLS	FE	FE-IV	POLS	FE	FE-IV
	(1)	(2)	(3)	(4)	(5)	(6)
Urban pop	0.652^{***}	0.671^{***}	0.648^{**}	0.192	0.202	0.167
	(0.243)	(0.187)	(0.257)	(0.243)	(0.254)	(0.257)
GDP	0.606	0.951^{***}	1.172^{***}	0.132	0.433	0.636
	(0.375)	(0.303)	(0.416)	(0.375)	(0.392)	(0.416)
Population	-0.528^{***}	-0.646^{***}	-0.681^{***}	-0.066	-0.165	-0.191
	(0.178)	(0.179)	(0.185)	(0.178)	(0.186)	(0.185)
Industry	0.182	0.028	-0.115	0.723^{***}	0.592^{**}	0.468
	(0.274)	(0.239)	(0.292)	(0.274)	(0.278)	(0.292)
Democracy	-0.085	0.058	0.032	0.224	0.367^{*}	0.349^{*}
	(0.156)	(0.166)	(0.187)	(0.156)	(0.189)	(0.187)
Time effects	No	Yes	Yes	No	Yes	Yes
Observations	1,363	1,363	1,318	1,353	1,353	1,309
R^2	0.747	0.766	0.763	0.753	0.760	0.762
Adjusted R^2	0.746	0.759	0.756	0.752	0.753	0.755
F Statistic	801.373^{***} (df = 5; 1357)	865.767^{***} (df = 5; 1323)	$4,150.909^{***}$	820.960^{***} (df = 5; 1347)	832.028^{***} (df = 5; 1313)	$4,084.181^{***}$

Note: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$
POLS is pooled OLS; FE is fixed effects; FE-IV is fixed effects instrumental variable estimation. For models (2), (3), (5) and (6), the null hypothesis of the Hausman test was rejected. There is no cross-sectional dependence for all the models. All the models exhibit serial correlation of idiosyncratic errors and heteroskedasticity. Consequently, using the Arellano heteroskedasticity-consistent covariance estimator, serial correlation and heteroskedasticity consistent robust standard errors are reported in parentheses. For the FE-IV estimation, the instruments include one period lagged GDP, urban population, total population, industry, governance, and year dummy variables.

Table *3.3* presents the results of estimating Equation (3.1) using the three general feasible generalised least squares (GLS) models: one with fixed effects (Columns (7) and (10)), one unrestricted with individual effects (Columns (8) and (11), and one unrestricted with time effects (Columns (9) and (12). The magnitude of the coefficients are similar to those of the FE and FE-IV estimations in Table

3.2. General FGLS is more suitable for situations where the number of groups is significantly larger than the number of time periods. Given the long panel used in this analysis, the standard errors become biased downwards, which explains the significance of the coefficients in Table *3.3*.

Table 3.4 presents the results of the two-step system GMM estimation of the dynamic model presented in Equation (3.7). In Columns (13) and (14), the dependent variable is regressed on the lagged dependent variable, urban population, GDP, total population, industry value added and governance.

The number of instruments in all estimations is high relative to the number of groups (this point is discussed in the literature, see Roodman (2007) and Roodman (2009)). One reason for the large number of instruments is the inclusion of the year dummies, which is unavoidable given the purpose of the estimation. On the p-value of the Hansen test, the general sentiment is that a p-value closer to 0 is more of a concern (Roodman (2009).

3.5 Discussion

First, a panel model is estimated using POLS, FE and FE-IV estimators. The impact of urbanisation on total energy consumption is consistently positive and significant for all three estimators, and not significant for electricity consumption. The results of the FE model estimation show that a 1% increase in the urban population increases total energy consumption by 0.65%, and the FE-IV estimation shows that a 1% increase in the urban population increases total energy consumption by 0.67%. GDP has a positive and significant impact on total energy consumption, but not on electricity consumption. This makes sense because of the low electrification rate in most of the countries in the sample, and the inability of low-income households, which make up the majority of the populations in the countries in the sample, in both urban and rural areas to access or pay for electricity.

Table 3.3 - Estimation results of the static model using different estimators.

	Energy type					
	Total energy consumption			Electricity consumption		
	FEGLS	U-GLS	U-GLS	FEGLS	U-GLS	U-GLS
	(7)	(8)	(9)	(10)	(11)	(12)
Urban population	0.677^{***}	0.682^{***}	0.631^{***}	0.246^{***}	0.194^{***}	0.283^{***}
	(0.004)	(0.003)	(0.033)	(0.003)	(0.004)	(0.028)

	Energy type					
	Total energy consumption			Electricity consumption		
	FEGLS	U-GLS	U-GLS	FEGLS	U-GLS	U-GLS
GDP	0.933***	0.490***	0.217***	0.517***	0.112***	-0.005
	(0.005)	(0.003)	(0.040)	(0.003)	(0.004)	(0.095)
Population	-0.645***	-0.512***	-0.217***	-0.187***	-0.065***	-0.040
	(0.003)	(0.003)	(0.043)	(0.003)	(0.004)	(0.025)
Industry	0.036***	0.233***	0.093***	0.480***	0.741***	0.676***
	(0.003)	(0.003)	(0.008)	(0.002)	(0.003)	(0.007)
Democracy	0.058***	-0.077***	-0.058***	0.254***	0.227***	0.143***
	(0.003)	(0.002)	0.006)	(0.001)	(0.002)	(0.004)
Fixed effects	Yes	No	No	Yes	No	No
Time effects	Yes	Yes	No	Yes	Yes	No
No of observations	1,363	1,363	1,363	1,353	1,353	1,353
R-squared	0.780	0.746	0.621	0.774	0.753	0.735

***p < 0.001; **p < 0.01; *p < 0.05
FEGLS is fixed effects generalised least squares; U-GLS is unrestricted generalised least squares.

Table 3.4 - Estimation results of the dynamic model.

	Energy type	
	Total energy consumption (13)	Electricity consumption (14)
Dependent variable (1st lag)	0.579***	0.530***
	(0.017)	(0.042)
Urban pop	0.248***	0.130**
	(0.025)	(0.041)
GDP	0.009	0.185***
	(0.034)	(0.051)
Population	-0.177***	-0.126***
	(0.024)	(0.035)
Industry	0.241***	0.267***
	(0.027)	(0.041)
Democracy	0.017	0.100**
	(0.022)	(0.034)
Constant	-0.071***	0.039*
	(0.014)	(0.017)
No of observations	1140	1140
No of groups	37	37
Hansen test of overid: Statistics	0.00	0.00
Hansen test of overid: p-value	1.00	1.00
No of instruments	46	46
Year dummies	Yes	Yes

***p < 0.001; **p < 0.01; *p < 0.05

Note: All estimations use the system GMM estimator of Blundell and Bond (1998) in two steps. The instrument matrices are collapsed. For the equation in first differences, lags 3 to 7 of the dependent variable are used as instruments. Windmeijer-Sigmund robust standard errors are reported in the parentheses. Statistic and p-value of the Hansen (1982) test of overidentifying restrictions are provided. Year dummies are included in all specifications, but coefficients are emitted.

An increase in the size of the economy does not guarantee electricity access for most of the population in both rural and urban areas. The population variable is negative in all the models but has a larger and significant negative relationship with total energy consumption. This can be explained by a faster rate of increase in population with respect to energy use, other things being equal. Not surprisingly, industry value added has a positive and significant impact on electricity consumption but not on total energy consumption. Quality of governance has a positive and significant impact on electricity consumption but no impact on total energy consumption. This is consistent with the empirical results of Brown and Mobarak (2009) and Ahlborg et al. (2015).

Second, generalised feasible general least squares estimation models are estimated for robustness (Table *3.3*). The magnitude of the coefficients for the urbanisation variable are consistent with the results in Table *3.2*. The statistical significance of coefficients in the model is a result of the long time series for each group in the dataset, and hence the errors are biased downwards. The magnitude of the control variables – GDP, population, industry and democracy – are similarly consistent with the original estimation. The governance variable is similarly small (and negative in Columns (8) and (9)) for total energy consumption and relatively large for electricity consumption.

Finally, the results of estimating the dynamic model (Table 3.4) show that the lagged dependent variable explains a significant portion of current consumption. This is evidence of the necessity of estimating a dynamic model. The coefficients of the covariates can be interpreted as short-run elasticities. The results of the dynamic model also show that, for total energy consumption, a 1% increase in urban population increases total energy consumption by 0.25% in the short run and 0.59% in the long run.[12] For electricity consumption, a 1% increase in the urban population increases electricity consumption by 0.13% in the short run and 0.28% in the long run. Like the static model, in the dynamic mode, the quality of governance indicator is small and not significant for total energy consumption and positive and significant for electricity consumption. Again, interpreting the magnitude of the governance variable is not important, but the results show a significant long-term impact of governance on electricity consumption.

[12] Where the long run elasticities are calculated from the short run parameters as $LR = \frac{SR}{1-\phi}$.

There are two particularly interesting findings from the estimation results of the static and dynamic models: first, urbanisation has a positive and significant impact on total energy consumption and a small to negligible impact on electricity consumption; and second, quality of governance has a positive impact on electricity consumption and no impact on total energy consumption.

A significant relationship between urbanisation and total energy consumption is verified by the consistency of the results. These results are intuitive considering the energy mix of most Sub-Saharan African countries, where fossil fuels and biomass make up most of total energy consumption. Much of the population relies on fuelwood, coal, and other biomass products for everyday energy use and fossil fuels are the main source of energy for transportation. Given that electricity access is limited, in both rural and urban areas, an increase in the urban population should not automatically translate to an increase electricity use. As of 2010, almost a third of the increase in the urban population is due to rural-urban migration (McGranahan *et al.*, 2009). And considering this migratory behaviour is a phenomenon among low-income groups, it is likely that new urban residents settle in parts of urban areas that are generally poorer, less electrified or where electricity is unreliable. Similarly, even when natural urban population growth becomes the biggest contributor to the increase in urban population (McGranahan *et al.*, 2009), the increase in urban population will be driven by households with low levels of female education in low-income neighbourhoods where fertility is generally higher (Bongaarts, 2020).

The relationship between quality of governance and electricity consumption has been theorised before. Brown and Mobarak (2009) find that in poor countries democracy increases the share of electricity consumed by the residential sector relative to industry. The authors suggest that sectors with less financial power benefit under democracy where their votes count. Similarly, Ahlborg et al. (2015) find that democracy and quality of institutions have a positive effect on household electricity consumption. The authors highlight the importance of institutions, just as economic development, in the provision of public services like electricity. The results in this chapter support these findings, but further research is required to understand why governance drives investment in electricity supply and where supply is being directed. This is particularly important because electricity access is a major impediment to development efforts in the continent.

The following chapter (Section 4) explores this relationship further from a different perspective: access to electricity as opposed to consumption. This distinction is important because of several factors. First, given that expansion of electricity access is capital intensive, an increase in consumption does not necessarily mean increases in access. Second, because of the relatively small size of the industrial sector in most Sub-Saharan African countries, it’s almost inevitable that the residential sector will dominate electricity consumption. Finally, because access is a better indicator of public service provision than consumption, and because consumption can increase as a result of economic gains in certain sectors or within specific income groups, it is possible to hypothesize about the potential impacts of increasing access versus the impacts of increasing consumption and hence draw conclusions on the wider implications of good quality institutions.

4 Chapter 4: Institutions and electricity access

4.1 Framing

The results of the previous chapter show evidence of a relationship between governance and electricity consumption across Sub-Saharan African countries. The relationship is robust to different estimation methods and in both the static and dynamic models. This is in line with existing literature on the positive impacts of governance on electricity consumption. The literature, more specifically, shows evidence of a positive relationship between governance and electricity consumption in the residential sector (Brown and Mobarak, 2009; Ahlborg *et al.*, 2015). However, within the Sub-Saharan African context, more consumption does not necessarily signal more access. For example, economic growth resulting from good governance could induce higher industrial consumption or can lead to higher incomes, and hence more consumption, at the household level for households already connected to the grid.

For governance to be truly transformative it must increase access too. (Trotter, 2016) shows that governance has a positive impact on rural electricity access. This fits well within the existing political science literature on the relationship between governance and service provision. There is, however, a discrepancy between the findings of Trotter (2016) on governance and rural electricity access and Brown and Mobarak (2009) and Ahlborg et al. (2015) on governance and electricity consumption. Taken together, these findings suggest that democracy increases residential electricity consumption (or per capita household consumption of electricity) partially through connecting more rural households to the grid. However, acknowledging that most rural households are poor, increases in rural electricity access might not be sufficient to drive aggregate electricity consumption. The aim of this chapter is to contribute to this debate through focusing on the second research question of this thesis: What is the relationship between governance and urban electricity access?

The history of electrification in South Africa, whether the electrification of mining towns in colonial South Africa, the white-only electrification policies of the

Apartheid regime, or the ambitious post-Apartheid electrification programme of the ANC, is an excellent example of the political nature of public service provision. After the African National Congress's (ANC) election win in 1994, South Africa's first constitutional democracy embarked on an ambitious electrification programme. The programme was part of a broader Reconstruction and Development Programme that was aimed at increasing access to services for the black population, who suffered from decades of Apartheid rule. Between 1948 and 1994, only white areas were fully electrified. This was feasible because the Population Registration Act of 1950 classified people into four racial groups, and the Group Areas Act of 1950 determined the residential areas where those racial groups lived. In townships, where most black people lived, only 1 in 3 households had access to electricity. The roll out of the electrification programme, led by Eskom, the national utility, was implemented through the municipalities, an autonomous tier of government, which were now seen as having a role in the development of the peripheries (Essex and de Groot, 2019). Areas with majority support for the ANC were prioritised in the electrification efforts, either through the municipalities or Eskom (Kroth, Larcinese and Wehner, 2016). The programme was a success: the electrification rate increased from 58% in 1996 to 85% in 2011.

In this chapter, institutions are defined as, "… the rules of the game in a society… that shape human interaction. In consequence, [institutions] structure incentives in human exchange, whether political, social, or economic" (North, 1990, p. 3). Or, put differently, institutions are the rules that humans collectively derive to govern their interactions. A distinction is made between formal and informal institutions as defined by Helmke and Levitsky (2004), where formal institutions are widely communicated, official, codified rules of engagement and informal institutions are unwritten socially shared rules and conventions administered outside official channels. This chapter is only concerned with formal institutions. Moreover, institutions determine the constraints on the behaviour of individuals and organisations and the "… conditions [under which] individuals [and organisations] are permitted to undertake certain activities" (North, 1990, p. 4). Within this framework, the quality of institutions improves the more limits there are on individuals and on executive power. Throughout the chapter, institutional quality and quality of governance are used interchangeably, and both refer to institutions as defined above. Autocratic governments (or autocracies) are assumed to have lower quality institutions – less constraints on executive power – and democratic governments (or democracies) are assumed to have higher quality institutions – more constraints on executive power.

Politics and institutional quality play a crucial role in the success of delivery of public services. Electricity, a vital public service, is commonly used as a political tool. Electricity provision can be manipulated to influence the outcome of elections, and the level of corruption affects access levels. The political drivers of electrification in developing countries are varied. Some of the motivations for electrification projects, like other development programs, stem from international funding and political support. One reason being that building electricity infrastructure is expensive, especially in rural areas where there are low population densities, isolated settlements and uneven terrain. This is unattractive to the private sector. With the responsibility to electrify, national governments can either embark on ambitious electrification projects, as in South Africa (above), Brazil (Coelho and Goldemberg, 2013) and Thailand (Shrestha *et al.*, 2008), or lure the private sector by lowering entry barriers (as in the U.S. in the 1930's (Lewis, 2018)) and creating markets (through subsidies and special financing arrangements (Zomers, 2003; Banerjee *et al.*, 2008; Ahmed, Trimble and Yoshida, 2013; de la Fuente, Rosales and Jellema, 2017)). Like most other public services, most of the electricity infrastructure in developing countries is centralised and bundled. Governments have a monopoly over the supply of electricity and investment in electricity infrastructure. Therefore, the political and administrative systems of government have the responsibility of either providing access to electricity themselves or creating the conditions to incentivise others to do it. Essentially, the task of providing access to electricity is a political one.

How governments in Sub-Saharan African countries enact this responsibility is the topic of this chapter. There is no guarantee that better institutions and the process of democratisation will be good for electrification. Governments acting under electoral constraints are keen to show their commitment to service provision to win votes. This is especially important in the nascent democracies of Sub-Saharan Africa. With limited resources, and a majority rural population, there is often a trade-off between economic and political incentives. For example, increasing access and reliability of electricity in urban areas can induce industrial growth and increase productivity, whereas increasing access in rural areas can guarantee more votes. Unlike democracies, autocratic governments are not constrained by elections, but by the more immediate threats of popular protests and coups. Therefore, engaging in clientelist governance, and keeping certain population groups happy, is a popular policy choice. These different incentives translate into different electrification policies. Although it's likely that the government has a monopoly over electricity supply in both cases, democratic governments are more likely to adopt power sector reform policies to reduce corruption and increase efficiency, and autocratic regimes are more inclined to support infrastructure investment because they present more opportunities for corruption and to reward supporters. For the two types of governance, incentives matter. These incentives then inform certain policies that ultimately determine the state of electricity access in Sub-Saharan African countries.

This chapter is organised as follows. The next section presents the research proposition. The subsequent section presents the data used and estimation methodology adopted. The following section discusses the findings of the empirical analysis. This is followed by a case study analysis of three countries with varying degrees of urban electricity access and quality of governance.

4.2 Research proposition

To fully answer the second research question in Chapter 1, "What is the relationship between governance and urban electricity access?", and noting the gap in the literature presented in Section 2.5, a proposition is presented on the relationship between institutions and urban electricity access in Sub-Saharan Africa.

The relationship between the quality of institutions and public service provision has been studied extensively. Governments function well under certain conditions: regular elections for the executive and legislative body, and informed citizens. In a democracy, where elections are held regularly, public officials act under the constraint of getting voted out of office and try to appease their constituents. As a result, more inclusive governments – governments with better institutions and better governance – tend to provide better education, infrastructure, security, and other public services. Electricity access, like other public services, also depends on the quality of governance.

Politicians in a democracy target large numbers of people. Public service provision can be used to win votes. Electricity, a conveniently verifiable public service, is commonly used as a political tool. Therefore, politics is a driver of electrification. This is more pronounced today in countries and regions where significant portions of the population lack access to electricity.

The relationship between institutional quality and electricity access is not straightforward. Many electrification projects in developing countries have failed because of weak institutions (Senegal's PASER and Kenya's KSEP). But the initiation of those same projects requires political pressure and good governance, usually targeting larger rural populations. Furthermore, there is evidence that government effectiveness, control of corruption and regulatory quality are not important factors for energy access.

The literature reviewed in Section 2.3.4 tells several stories. First, democracy has a positive effect on residential electricity consumption (but not on industrial electricity consumption). This implies that more democratic governments prioritise the residential sector, because of the large number of people, over the industrial sector, because it represents a smaller number of people. Second, democracy is especially conducive to residential electricity consumption in poorer countries. For example, if country A is poorer than country B, the positive effect of democracy on residential electricity consumption is positive in both countries, but larger in country A. This means that nascent democracies are more likely to prioritise the residential sector over other sectors. But it could also mean that there is more room for improvement in electricity access in poorer countries. Finally, in developing countries, institutional quality is conducive to electricity consumption in general. Because the residential sector accounts for the largest portion of total electricity consumption, a similar conclusion can be made in that good quality institutions have a positive effect on residential electricity consumption.

These narratives are similar. They emphasise the positive effect of institutional quality on electricity consumption. And given that electricity consumption is historically positively correlated to income, the logic can be extended to a relationship between institutional quality and income. There are numerous studies on the relationship between institutional quality and income, most of which make the same logical conclusion. However, there are a couple of limitations to these narratives. First, an increase in residential electricity consumption relative to industry is not necessary a good thing. It could imply an increase in consumption without increases in production: no proportional increase in industrial activity. Second, developing countries have low electricity access rates, therefore, any increase in electricity consumption, which will inevitably be in the residential sector, is very likely to be an increase for those who already have access to electricity, and not for those who need it. Third, if the democratic process increases residential electricity consumption, it could well mean that, in a nascent democracy, the political process has led politicians to prioritise the urban, already-electrified population over industry to win votes.

The political processes that dictate these relationships can be explored in more detail. Furthermore, the urban population is often overlooked in studies on increasing electrification. It is only considered within the context of reliable electricity access for urban slums. It can be argued that, because of its political significance, urban electrification could reveal the underlying political processes behind public service provision. Accordingly, this study explores the relationship between governance and urban electrification by making the following proposition.

Proposition: democratic governments are subjected to electoral constraints. Public service provision is one way of securing votes. Electricity is an effective and verifiable public service. In Sub-Saharan African countries, most the population is rural and poor. Therefore, democratic governments will prioritise rural electrification. On the other hand, autocratic governments are not constrained by elections. Urban residents pose the biggest political threat to autocratic governments. Because electricity is a useful political tool, autocratic governments prioritise urban electrification.

4.3 Exploratory analysis

To tackle the question on the relationship between governance and electricity access, an exploratory analysis was conducted using aggregate-level data for a sample of Sub-Saharan African countries. The six governance indicators from the World Bank's World Governance Indicators database (World Bank, 2020b) were averaged to create a composite indicator. The composite indicator was then plotted against urban electricity access data from the World Bank's World Development Indicators database (World Bank, 2020a).

The macro-level data shows that the relationship between governance and electrification is different for rural and urban areas. The data for 2018 (the latest year for which data is available for all the countries in the sample) might encourage the conclusion that governance has a positive relationship with urban electricity access (Figure *4.1*). The figure shows that countries with a higher governance rating tend to have higher levels of urban electricity access. The trend line is more positive for rural electricity access.

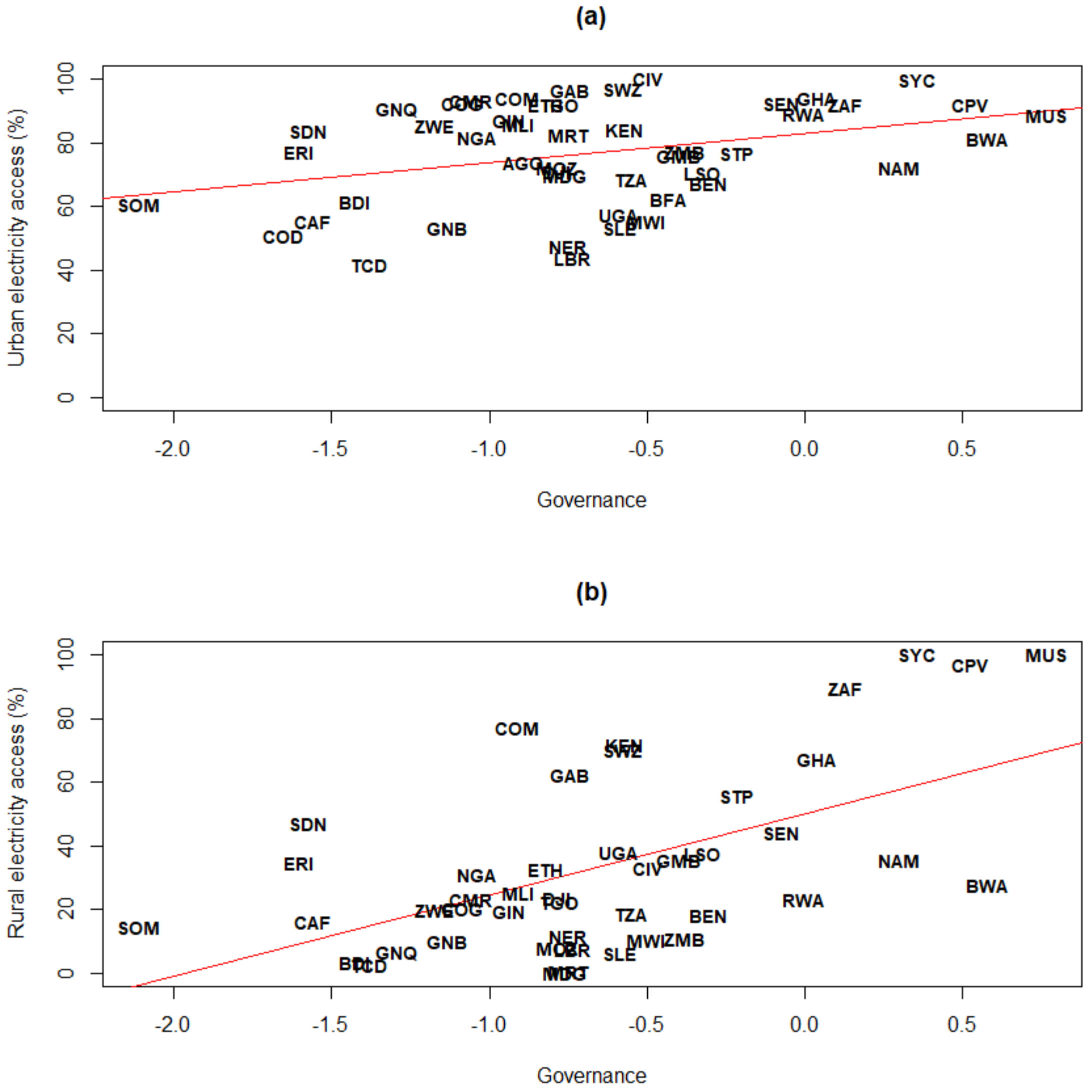

Figure 4.1 - (a) Urban electricity access against governance for 48 Sub-Saharan African countries; (b) Rural electricity access against governance for 48 Sub-Saharan African countries (data is for 2018) (urban electricity access data is from (World Bank, 2020a) and governance data is from (World Bank, 2020b))[13].

[13] Country codes: AGO – Angola; BEN – Benin; BWA – Botswana; BFA – Burkina Faso; BDI – Burundi; CPV – Cabo Verde; CMR – Cameroon; CAF – Central African Republic; TCD – Chad; COM – Comoros; COD – Democratic Republic of Congo; COG – Republic of Congo; CIV – Cote d'Ivoire; GNQ – Equatorial Guinea; ERI – Eritrea; SWZ – Eswatini; ETH – Ethiopia; GAB – Gabon; GMB – Gambia; GHA – Ghana; GIN – Guinea; GNB – Guinea Bissau; KEN – Kenya; LSO – Lesotho; LBR – Liberia; MDG – Madagascar; MWI – Malawi; MLI – Mali; MRT – Mauritania; MUS – Mauritius; MOZ – Mozambique; NAM – Namibia; NER – Niger; NGA – Nigeria; RWA – Rwanda; STP – Sao Tome and Principe; SEN – Senegal; SYC – Seychelles; SLE – Sierra Leone; SOM –

More importantly, the relationship between governance and urban electricity access appears less obvious over time. Figure *4.2* shows that a lot of the countries in the sample exhibit a negative relationship between governance and urban electricity access over time. In the figure, governance is plotted against urban electricity access for the same sample of Sub-Saharan African countries for the period 2000 to 2018. A trend line is plotted for each country's time series. The graph is divided up into four quadrants: the top right quadrant is where countries have relatively good governance with higher urban electricity access (between 50% and 100%); the bottom right quadrant is relatively good governance with lower urban electricity access (between 0% and 50%); the top left quadrant is relatively bad governance and high urban electricity access; and the bottom left quadrant is relatively bad governance and low urban electricity access. Most of the countries in the sample are in the two left quadrants. In some countries, increases in urban electricity access over time were achieved in parallel to increases in the quality of governance (equivalent to a move from the bottom left quadrant to the top left quadrant). In other countries, where the trend line slopes to the left (or almost vertical), there appears to be a negative relationship (or no relationship) between governance and urban electricity access, where, over time, increases in urban electricity access are achieved in parallel to worsening governance.

The proposition made in Section 4.2 aims to provide an explanation for the relationship between governance and urban electricity access over time, and the rest of this chapter provides evidence in support of the proposition. The following section highlights the empirical and qualitative methodologies used to study the relationship between urban electricity access and governance.

Somalia; ZAF – South Africa; SDN – Sudan; TZA – Tanzania; TGO – Togo; UGA – Uganda; ZMB – Zambia; ZWE – Zimbabwe.

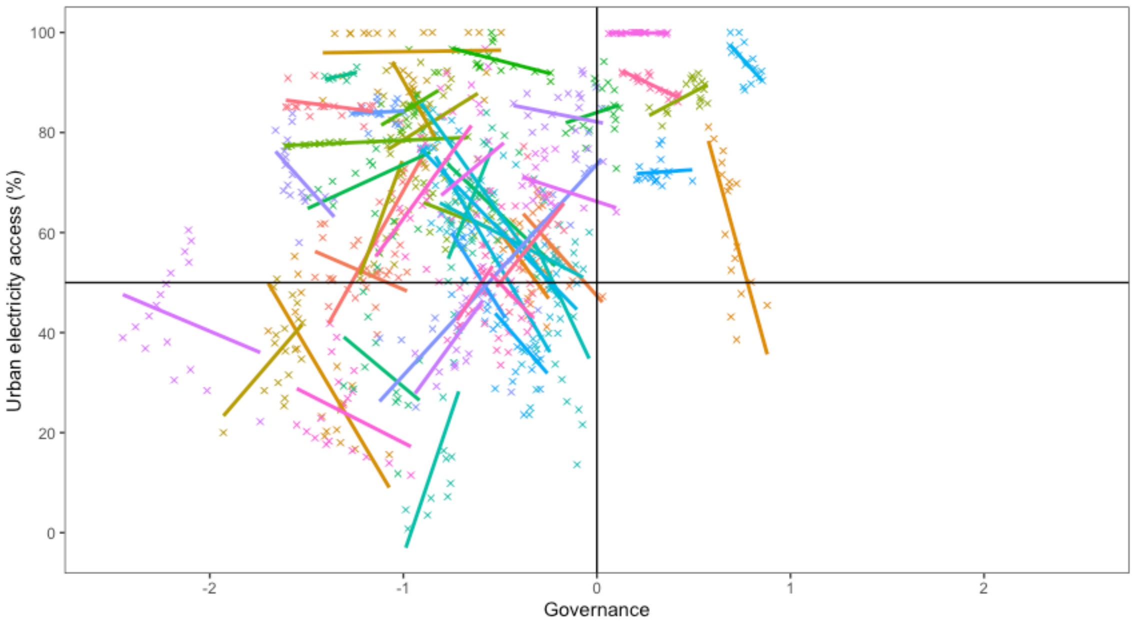

Figure 4.2 - Urban electricity access against governance for the period 2000 – 2018 (Note: the different colours represent different countries; a trend line is plotted for each country's time series).

4.4 Empirical research methodology

Empirical evidence is provided to support the proposition put forward in Section 4.2 using formal methods of inductive reasoning. The main empirical approach, using standard econometric methodology, examines the size, direction, and significance of a governance variable on urban and rural electricity access for Sub-Saharan Africa countries. This is complemented with a supplementary analysis of project-level data to determine the impact of governance on the likelihood of power and grid extension projects to serve urban areas. The analysis uses three different datasets. The first dataset comprises country level economic and demographic data and is used for the main empirical estimation. The second and third datasets comprise project-level data on power generation plants and transmission and distribution projects compiled by the author. from the World Bank Development Indicators database, and governance data from the World Bank Governance Indicators database, Freedom House and Polity IV databases. The second and third datasets are project level datasets on power generation plants, and on transmission and distribution projects, compiled by the author from the World Bank's Projects and Operations database and Private Participation in Infrastructure database, and the World Resource Institute's Global Power Plants

Database. The empirical exercise assumes that all the countries in the sample exhibit similar urban-bias as a result of the pre- and post-colonial policies discussed in Section 2.1, and the difference in level of urban-bias is due to country fixed effects.

4.4.1 Data

The data used in the main estimation exercise is obtained from several sources. Data on electricity access, urban and rural populations, per capita GDP, population density, aid and total population is from the World Development Indicators database (World Bank, 2020a). The six governance indicators are from the World Governance Indicators database (World Bank, 2020b). The Freedom House and Polity IV democracy indicators are from the Freedom House (Freedom House, 2018) and Polity IV (Marshall, Gurr and Jaggers, 2019) databases, respectively. The dataset is an unbalanced panel of 44 Sub-Saharan African countries spanning the period 2000 to 2014.

The dependent variables are the total number of people in urban and rural areas with access to electricity. The six governance indicators, and their average, are measured on a 5-point scale between -2.5 to 2.5. Per capita GDP and aid are measured in current US Dollars. Population density is the number of people per square kilometre and population is the total number of people in the country. The Freedom House democracy indicator is an average of political rights and civil liberties indicators, each having a 7-point scale between 1 and 7. The Polity IV indicator is a sum of Polity IV's democracy and autocracy indicators. The democracy indicator uses an 11-point scale, between 0 and 10, as a measure of a country's institutionalised democracy. The autocracy indicator uses a 10-point scale, between -1 and -10, as a measure of country's institutionalised autocracy. The final Polity IV indicator, therefore, has a range between -10 and 10. The State Fragility indicator from the Polity IV database scores countries on a 26-point scale, between 0 and 25, on effectiveness and legitimacy of four dimensions: economic, security, political and social. Table *4.1* presents the summary statistics for all the variables used in the first estimation.

The second and third datasets are compiled by the author from the World Banks Projects and Operations Database (World Bank, 2021), the World Bank's Private Participation in Infrastructure (PPI) database (World Bank, 2022), and the World Resources Institute's Global Power Plant Database (World Resources Institute, 2022).

The second dataset comprises data on power projects. The dependent variable is a dummy variable that takes a value of 1 if a power project is built to serve an urban area, and 0 otherwise. This variable was created by analysing project documents, where available, or by locating the power plant on the map. For hydro projects, where the location is determined by geographical constraints, project documentation was the only feasible option to ascertain the target service area. In the absence of project documents, the project was not included.

Table 4.1 - Summary statistics.

Descriptive statistics							
Statistic	N	Mean	St. Dev.	Min	Pctl(25)	Pctl(75)	Max
Urban electricity access (log)	866	6.2	0.7	4.1	5.7	6.7	7.9
Rural electricity access (log)	771	5.6	0.8	3.3	5.0	6.1	7.7
Control of corruption	864	-0.6	0.6	-1.9	-1.1	-0.3	1.2
Government effectiveness	864	-0.8	0.6	-2.4	-1.2	-0.5	1.1
Political stability	864	-0.5	0.9	-3.3	-1.2	0.1	1.3
Regulatory quality	864	-0.7	0.6	-2.6	-1.1	-0.3	1.1
Rule of law	864	-0.7	0.7	-2.6	-1.2	-0.3	1.1
Voice and accountability	864	-0.6	0.8	-2.2	-1.2	-0.1	1.0
WGI (average)	864	-0.7	0.6	-2.4	-1.1	-0.3	0.9
Freedom House	912	4.3	1.7	1	3	5.5	7
State fragility	828	14.8	5.1	0.0	12.0	18.0	25.0
Polity IV	813	2.3	5.3	-9.0	-2.0	7.0	10.0
per capita GDP (log)	885	3.0	0.5	2.0	2.7	3.3	4.4
Population density (log)	886	1.7	0.6	0.3	1.3	2.1	2.8
Aid (log)	869	8.8	9.2	-0.3	2.8	12.0	92.1
Population (log)	905	6.8	0.7	4.9	6.3	7.3	8.3

The main explanatory variable is a composite governance index, an average of the six World Governance Indicators, of the country in the year the project is being implemented. To account for the delayed effects of governance on project implementation, the analysis also employs the third and fifth lag of the governance indicator. The third and fifth lags of the governance indicator are also used to account for the typical lengths of election cycles in developing countries

(Chauvet and Collier, 2009) and their impact on policymaking in the electricity sector (Min and Golden, 2014; Baskaran et al., 2015). The control variables include GDP of the country in which the project is being implemented, the ownership structure of the project, the size of the project (in MW) and the total installed capacity in the country in which the project is being implemented. GDP is used to control for economic activity and demand for electricity. The variable for ownership structure takes a value of 1 if the project is more than 50% private, and 0 otherwise. This is used to control for the risk aversion of private capital and the preference for areas and regions with high demand for services (Vassallo and Soliño, 2006; Brandao and Saraiva, 2008). The variable for the size of the project takes a value of 1 if a project is 25 MW or more, and 0 otherwise, and this variable controls for the government's financial capacity. Finally, the total installed capacity variable controls for existing electricity generation capacity in the country.

The third dataset comprises data on transmission and distribution and grid extension projects. The dependent variable and main explanatory variable of the third dataset are the same as those of the second dataset and the dependent variable was created in the same way. The control variables in the third dataset include total project cost, total installed capacity and urban electrification rate. Total project cost controls for the government's financial capacity. And total installed capacity and urban electrification rate controls for existing electricity generation capacity and how much of that feeds urban areas.

4.4.2 Dependent variables

The dependent variables in this analysis are the number of people with access to electricity in urban and rural areas. The variables are created by multiplying the number of people in urban (rural) areas by the urban (rural) electrification rate. Access to electricity is chosen over other measures of electricity consumption, such as household electricity consumption used by Ahlborg et al. (2015), because access can be viewed as a measure of a government's ability, or effort, to provide access. Household electricity consumption, on the other hand, measures use of electricity by residents with access, who most likely reside in urban areas with relatively higher incomes. This doesn't give the desired measure of a government's efforts to provide electricity.

Based on the proposition made in Section 4.2, a positive correlation is expected between electricity access in rural areas and quality of governance, and a much less positive (negative for certain countries if measured in isolation) and statistically insignificant relationship between governance and urban electricity access.

Table 4.2 - Electrification data sources.

Source Author(s)	World Bank SE4ALL database, SE4ALL Global Tracking Framework (World Bank, 2020a)	Harvard Dataverse (2018), collected by Aklin, Harish and Urpelainen (2018)
Variables and definitions		
Total electricity access	Access to electricity (% of population) – the percentage of population with access to electricity.	Total electrification rate – percentage of total households in the country who have access to grid electricity.
Urban electricity access	Access to electricity, urban (% of urban population) – the percentage of urban population with access to electricity.	Urban electrification rate – percentage of urban households in the country who have access to grid electricity.
Rural electricity access	Access to electricity, rural (% of rural population) – the percentage of rural population with access to electricity	Rural electrification rate – percentage of rural households in the country who have access to grid electricity.
Methodology	Data collected from different sources: Demographic and Health Surveys (DHS), Living Standards Measurement Surveys (LSMS), Multi-indicator Cluster Surveys (MICS), World Health Survey (WHS), other national developmental and implemented surveys, various government agencies. A simple modelling approach to fill in missing data points: for 1990, 2000 and 2010. Each country has 0 to 3 data points. Countries with 0 data points, a weighted regional average is used as estimate. Countries with 1 to 3 data points, missing data is estimated with a model with region, country and time variables. Data begins from year with first survey data available for each country.	Research assistants tasked with searching electrification rates for specific countries. National census reports: Google "[country name] census [year]" to access reports on the census. National socio-economic surveys: Google "[country name] socio economic survey [year]" or "[country name] household budget survey [year]". Sources MUST be: country office of statistics website; country ministries of energy or rural electrification authorities; country utilities; secondary literature: country case studies. Sources NOT to be used: World Bank, EIA, IEA, WHO or IRENA, or secondary material that uses these sources.
Advantages	Data available for all 48 Sub-Saharan African countries.	Uses country reports instead of multilateral organisations. Not a lot of extrapolation.
Disadvantages	Inconsistency in data. Aggregation methodology makes unrealistic assumptions about regional similarities and time trends.	Data not available for all 48 Sub-Saharan African countries. A lot of gaps in the data.
Notes	Aggregation method: weighted average. Several countries have gaps in data due to low frequency and regional distribution of surveys.	Data almost exclusively from census surveys: imputed cases are rare and only when 2 or 3 variables are observed; share of rural/urban population used when a respective observation is missing. Country criteria: population > 300,000; relatively stable and open political system.

	Electrification defined as access to grid electricity: households connected to microgrids and other systems are excluded.

For the dependent variable, electricity access data from two databases is considered: data from (World Bank, 2020a), and electrification data compiled by Aklin, Harish and Urpelainen (2018). Table 4.2 below provides a comparison of the two databases.

Both datasets have their respective merits and drawbacks. And despite the Aklin dataset's many advantages, the gaps in the data are limiting. So, the empirical investigation will employ the World Bank data. Throughout the chapter, however, the Aklin dataset is used to mainly because the first datapoint in the World Bank dataset is 1993 for all countries. For some countries, the Aklin dataset goes back a bit further. For example, for Ghana, the first datapoint is 1988.

Similar studies in the literature use different measures of electrification. For example, Brown and Mobarak (2009) use residential share of total electricity consumption, Ahlborg et al. (2015) use annual household electricity consumption per capita, Onyeji, Bazilian and Nussbaumer (2012) use total electricity access and Trotter (2016) uses rural electricity access. Unlike these studies, this research is mainly concerned with the relationship between governance and electrification to the extent that it highlights the inclinations of different regime types towards providing access to electricity. For that reason, both rural and urban electrification rates are used.

4.4.3 Explanatory variables

The main explanatory variable is governance. As a measure of institutional quality, this research uses the World Bank's six governance indicators. The governance indicator used in the empirical analysis for project level data is an average of the six governance indicators: voice and accountability; political stability and absence of violence; government effectiveness; regulatory quality; rule of law; control of corruption. Table 4.3 provides details on the assessment criteria, the methodology used to compute the six indicators and the definition of each indicator.

Other "good governance" indicators include Transparency International's Corruption Perception Index (CPI), governance indicators from the International Country Risk Guide (ICRG), the Global Integrity index produced by Global Integrity, and several human rights indicators generated by the Cingranelli-Richards database. In the literature, different combinations of indicators are used as a measure of democracy and institutional quality. Brown and Mobarak (2009) use the Polity dataset to represent democracy and use quality of bureaucracy, corruption in government, government stability and socioeconomic conditions from ICRG's Political Risk Services as measure of quality. Ahlborg et al. (2015) use a Freedom House/Polity score created by Hadenius and Teorell (2005) as an indicator for democracy and use rule of law and control of corruption from the World Bank's Governance Indicators as measures of institutional quality[14].

Unlike the selective use of governance indicators in the literature, this research makes use of all six indicators. Ahlborg et al. (2015) elect not to use the voice and accountability and political stability indicators because their model already includes a measure of democracy, and political stability doesn't belong in the authors' theoretical definition of good governance. They also don't use the government effectiveness indicator because it includes a measure of the perception of provision of public goods and could "conflate the dependent and independent variables". On the other hand, Onyeji, Bazilian and Nussbaumer (2012) initially use a corruption index, regulatory quality index and government effectiveness index to measure the effect of institutional quality on total electricity access. They then exclude the corruption and regulatory quality indices from the analysis because of statistical insignificance, and only include government effectiveness as a measure of institutional quality.

This study deals with a broad and fluid definition of governance and makes assumptions about the tendency of certain types of regimes to act a certain way,

[14] The authors choose these two indicators out of the possible six because they fit the authors' "theoretical notions about the role of good governance in the provision of electricity".

and, therefore, requires the breadth and depth provided by all six governance indicators. Unlike Ahlborg et al. (2015), the estimation exercise used in this chapter does not include a measure of democratisation, which the voice and accountability index makes up for. Political stability is included because it reflects the embeddedness and long-term stability of governing institutions, which can influence how politicians design, formulate, and commit to certain policies. For example, policy implementation depends on how committed politicians are (Acemoglu, 2003).

Table 4.3 - World Governance Indicators (World Bank, 2020b).

Criteria	Detail
Assessment criteria	Trade and financial policies; business regulation; social sector policies; effectiveness of the public sector; and transparency, accountability, and corruption.
Data	
Frequency of compilation	Annual
Observations	1996 to today (biennial between 1996 and 2002)
Breadth	Six indicators based on data from 61 sources compiled by 25 different organisations.
Depth	The indicators are computed based on hundreds of variables, including: views of experts; firm surveys; citizen perceptions of various dimensions of governance.
Errors	There is a specified margin of error provided with the estimates of each observation for the six indicators.
The six indicators	
Voice and accountability	The extent to which a country's citizens can participate in selecting their government, as well as freedom of expression, freedom of association and free media.
Political stability and absence of violence	Perceptions of the likelihood that the government will be destabilised or overthrown by unconstitutional or violent means, including political violence and terrorism.
Government effectiveness	The quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies.
Regulatory quality	The ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development.
Rule of law	The extent to which agents have confidence in and abide by the rules of society, and the quality of contract enforcement, the police, and the courts, as well as the likelihood of crime and violence.

Control of corruption	The extent to which the public power is exercised for private gain, including both petty and grand forms of corruption, as well as 'capture' of the state by elites and private interests.

The government effectiveness indicator, other than reflecting citizens' perceptions of public service provision, of which electricity is only one, also includes the quality of civil service and policy formulation. Utilities in most Sub-Saharan African countries are state owned, and, as a result, their efficiency is susceptible to the quality of the civil service. The rule of law indicator measures the enforcement of contracts, and the confidence citizens have in societal rules, which is an integral piece of an inclusive institutional setup (Acemoglu, Johnson and Robinson, 2001; Acemoglu, Gallego and Robinson, 2014). The control of corruption indicator is considered because the analysis infers that one of the motivations for autocratic governments of investing in infrastructure projects is the opportunity of rewarding supporters through corrupt means. We expect more corrupt countries to be more autocratic and hence more willing to use public funds to reward supporters and satisfy urban electricity demand. The regulatory quality indicator, which measures governments' ability to promote and permit private sector development, is relevant despite the prevalence of state-owned utilities in the continent. It is expected that more autocratic governments to be less committed to inclusive private sector development, especially with respect to electricity access for industry.

4.4.4 Control variables

The control variables include GDP per capita, population density, development aid, and total population (Table 4.4). The model controls for GDP per capita because of the well-established relationship between energy access and economic growth (Ahlborg *et al.*, 2015; Trotter, 2016). Population density controls for the geographical dispersion of people in a country, which determines the feasibility and likelihood of electrification: the more sparsely populated a country is, the more expensive it is to electrify. The model controls for development aid. Although development aid accounts for a small percentage of infrastructure spending in Sub-Saharan Africa (Foster and Briceno-Garmendia, 2010), in nascent democracies aid is sometimes distributed for political purposes (see Ghana in Section 4.6.3). Finally, total population is included as a control variable because the two dependent variables are absolute values of urban and rural populations.

Table 4.4 - Control variables.

Variable	Definition	Source
GDP per capita	GDP per capita (current USD)	(World Bank, 2020a)
Population density	The total number of people divided by the land area (people per square kilometre)	(World Bank, 2020a)
Aid	Net official development assistance and official aid received (current USD)	(World Bank, 2020a)
Population		

4.4.5 Robustness checks

To check that the results of the analysis are robust to other perceptions, understanding and measures of institutional quality, measures of liberal democracy (Freedom House) and constitutional democracy (Polity IV) are used in place of the World Governance Indicators (Table 4.5). Both indicators are used for robustness checks for two reasons. First, they provide another measure of good governance: democracy (instead of institutional quality). While the existence, or lack, of a democracy is readily reflected in the governance indicators, the Freedom House and Polity IV indicators measure specific characteristics of democratic rule. Second, both indicators have enough observations for Sub-Saharan African countries. The Freedom House database has two indicators: political rights and civil liberties, both measured on a 7-point scale from 1 to 7 where 1 is “good” political rights and civil liberties and 7 is “bad.” The Polity IV database has four indicators: democracy, autocracy, Polity and state fragility. The democracy indicator is measured on an 11-point scale between 0 and 10, where 0 is lack of democracy and 10 is full democracy, and the autocracy indicator is measured on an 11-point scale from 0 and -10 where 0 is no autocracy and -10 is full autocracy. The Polity indicator is the summation of the democracy and autocracy indicators. The state fragility indicator measures state fragility on a 26-point scale between 0 and 25, where 0 indicates no fragility and 25 indicates high fragility.

Figure *4.3* shows urban electricity access plotted against the different measures of governance. There is a discernible positive relationship between the Governance variable (an average of the six World Governance Indicators) and urban electricity access. A similar trend can be seen for the relationship between urban electricity access and state fragility, where more fragile states (high state fragility score) have lower urban electricity access rates. There is no obvious relationship between the political rights and civil liberties, democracy and Polity variables and urban electricity access.

Table 4.5 - Different indicators for the measure of democracy.

	Freedom House	Polity IV
Data source	(Freedom House, 2018)	(Marshall, Gurr and Jaggers, 2019)
A measure of	Political rights and civil liberties	Democracy and Autocracy, State fragility
Observations	1972 to today	1800 to today
Scale	Continuous 7-point scale	Continuous 20-point scale for Democracy and Autocracy; Continuous 26-point scale for State Fragility
Attributes	Political rights: electoral process; political pluralism; functioning government. Civil liberties: freedom of speech; rule of law; human rights	Democracy: presence of democratic institutions and procedures; constraints on the power of the executive; citizens have civil liberties.
Strengths	Comprehensive scope	Long time scale
Weaknesses	Measurement problems	Aggregation problems

Other indicators of democracy, such as the Vanhanen (2000) index of democracy and the democracy and dictatorship (DD) measure generated by Przeworski et al. (2000), have some limitations. First, the index of democracy is a measure of electoral participation, and the DD index measures the extent to which elections are contested. This does not serve the purpose of this research because there is a limit to how much can be extrapolated from voter turnout and the degree of contestation of elections to institutional impacts on electricity access. Second, and most important, data is only available until the year 2000.

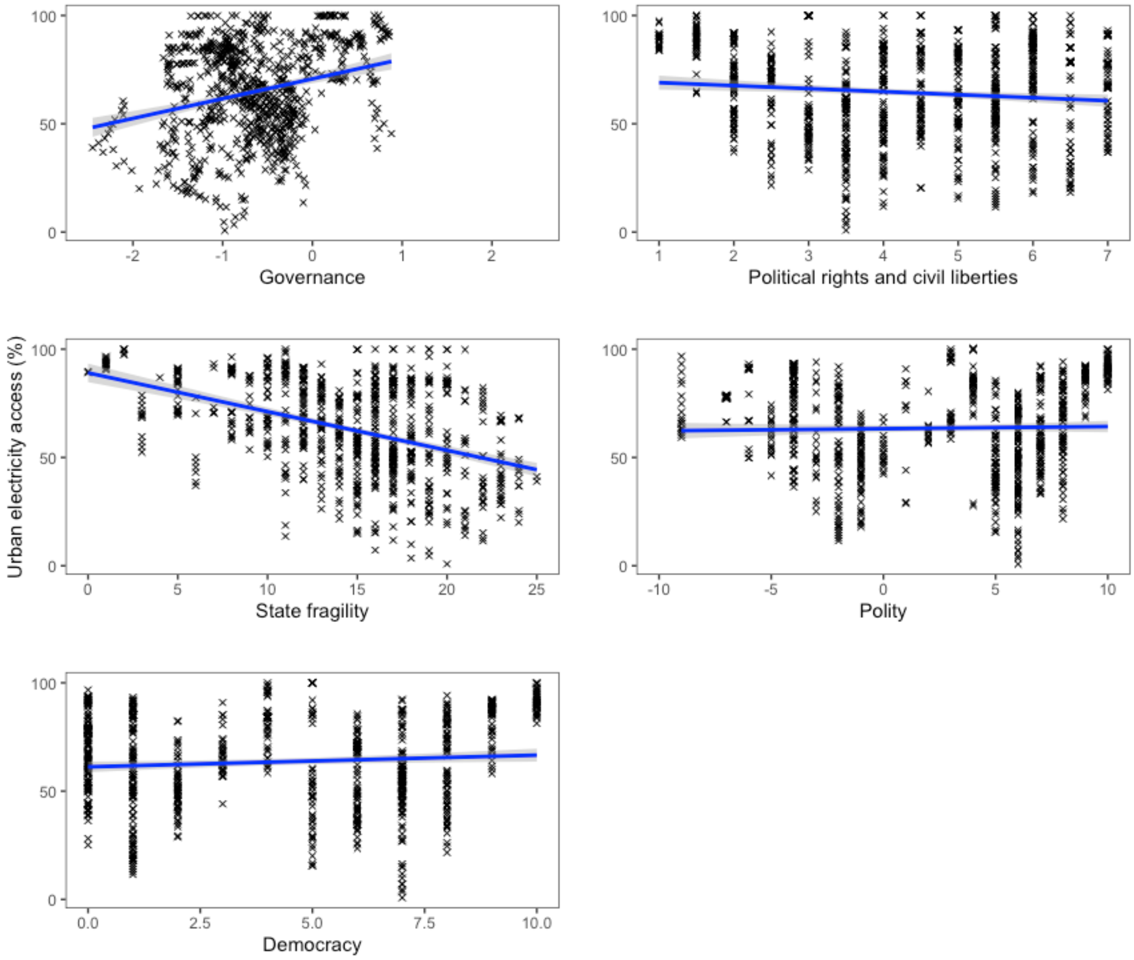

Figure 4.3 - Urban electricity access and different measures of institutional quality. (Note: the Governance variable is an average of the six World Governance Indicators (World Bank, 2020b); the Political rights and civil liberties variable is an average of the political rights and civil liberties indicators from the Freedom House database (Freedom House, 2018); the State fragility variable is from the Policy IV database; the Polity variable is a summation of the Democracy and Autocracy variables from the Polity IV database; the Democracy variable is a measure of democracy from the Polity IV database (Marshall, Gurr and Jaggers, 2019)).

4.4.6 Empirical estimation

The use of panel data over cross-sectional data has the added advantage of more observations. The main advantage of using panel data is the ability to account for country specific effects, which are assumed to be fixed over time, thus avoiding bias due to unobserved heterogeneity across countries. For that reason, the models estimated using fixed effects estimation. Fixed effects estimation is used to account for unobserved heterogeneity across countries.

The results are reported in the next section. Because of the ordinal nature of the main explanatory variables, the focus is on the statistical significance and sign of the coefficients. The data exhibits heteroskedasticity and autocorrelation, therefore, all the models report heteroskedasticity and autocorrelation consistent standard errors.

Using the panel dataset, the estimation is carried out for the original model for each of the size World Governance Indicators as the main explanatory variables. A series of robustness checks is then carried out using other measures of governance as the main explanatory variables: political rights and civil liberties from the Freedom House database, and democracy and state fragility from the Polity IV database.

To estimate the relationship between governance and electricity access two panel data models are estimated with two different dependent variables, number of people in urban areas with access to electricity and number of people in rural areas with access to electricity, using macro-level data for 44 Sub-Saharan African countries. Then, two logit models are estimated using project-level data to estimate the relationship between governance and power distribution to rural and urban areas.

The following model is estimated for each of the six World Governance Indicators using fixed effects estimation

$$log(y_{i,t}) = \beta_0 + \beta_1 wgi_{i,t,j} + \boldsymbol{\beta X}_{i,t} + e_{i,t} \tag{4.1}$$

where $y_{i,t}$ is the urban (or rural) population in country i at time t that has access to electricity. $wgi_{i,t,j}$ is governance indicator j, where $j \in (1,6)$, for country i at time t, $\boldsymbol{X}_{i,t}$ is a K-dimensional vector of explanatory variables, $\boldsymbol{\beta}$ is a (K × 1) vector of slopes, and e_{it} is an error term of idiosyncratic factors that influence the urban (or rural) population with access to electricity in country i at time t. As a robustness check, three more models are estimated using state fragility and democracy indicators from the Polity IV database, and democracy indicator from the Freedom House database.

e_{it} is an error term of idiosyncratic factors that influence energy consumption in country i at time t.

All the models estimated exhibit serial correlation and heteroskedasticity, therefore, serial correlation and heteroskedasticity consistent standard errors are reported for all models.

A second pair of models is estimated to determine the relationship between governance and urban electricity provision using project-level data. The following logit model is estimated

$$logit(p_{i,j,t}) = \beta_0 + \beta_1 gov_{j,t} + \boldsymbol{\beta X}_{i,j} + \gamma_t \quad (4.2)$$

where $p_{i,j,t}$ is a dummy variable that takes a value of 1 if power project i in country j implemented in year t is to supply electricity to an urban area, and 0 otherwise. $gov_{j,t}$ is a governance indicator for country j at the start year of the project, t, and $\boldsymbol{X}_{i,j}$ is a vector of project and country specific controls. Using project start year, a vector of year fixed effects, γ_t, is added to account for the change in financing policies over time. Lagged values of the governance indicator are used in further estimations as robustness.

The logit model is preferred over a linear probability model for two main reasons. First, because of the small sample size, the central limit theorem cannot be relied on to assume that the errors are normally distributed. Second, the linear probability model assumes the regressors have a linear relationship and can, therefore, make predictions about the probability of a power project being implemented to provide electricity to an urban area that is greater than 1 or less than 0.

4.5 Results of the empirical estimation

Table *4.6* presents the results of estimating Equation (4.1). The rural and urban populations with access to electricity are regressed on governance, per capita GDP, population density, development aid, and total population. The same model is estimated for each of the six World Governance Indicators: control of corruption, government effectiveness, political stability, regulatory quality, rule of law, and voice and accountability. The main explanatory variables and the control variables are statistically significant in all the models. All the governance variables, except for political stability, have the expected values: positive and significant for rural electricity access, and negative and significant for urban electricity access.

Table *4.7* presents the results of the same estimation but using different measures of institutional quality: Freedom House democracy indicator, and Polity IV democracy and state fragility indicators. The only significant coefficient for the alternative governance indicators is for State Fragility on rural access to electricity. Despite that, the coefficient for state fragility on urban electricity access and the coefficients for Political Rights and Civil Liberties on both rural and urban electricity access have the expected signs.

Table 4.6 - Results of panel model estimation using the World Bank's six World Governance Indicators.

	Dependent variable: Number of people with access to electricity											
	Rural (1a)	Urban (1b)	Rural (2a)	Urban (2b)	Rural (3a)	Urban (3b)	Rural (4a)	Urban (4b)	Rural (5a)	Urban (5b)	Rural (6a)	Urban (6b)
Corruption	0.262***	-0.020***										
	(0.009)	(0.002)										
Government effectiveness			0.191***	-0.057***								
			(0.013)	(0.002)								
Political stability					0.001	0.009***						
					(0.004)	(0.002)						
Regulatory quality							0.088***	-0.063***				
							(0.015)	(0.002)				
Rule of law									0.163***	-0.059***		
									(0.011)	(0.003)		
Voice and accountability											0.109***	-0.014***
											(0.009)	(0.002)
per capita GDP	0.356***	0.461***	0.372***	0.500***	0.564***	0.440***	0.488***	0.495***	0.418***	0.495***	0.462***	0.459***
	(-0.011)	(-0.001)	(-0.016)	(-0.002)	(-0.004)	(-0.001)	(-0.017)	(-0.001)	(-0.015)	(-0.002)	(-0.012)	(-0.001)
Population density	0.405***	0.019***	0.399***	0.028***	0.436***	0.016***	0.424***	0.026***	0.403***	0.029***	0.416***	0.019***
	(-0.001)	(0.001)	(-0.004)	(0.001)	(-0.001)	(0.001)	(-0.002)	(0.001)	(-0.003)	(0.0005)	(-0.002)	(0.00005)
Aid	-0.017***	-0.005***	-0.015***	-0.004***	-0.012***	-0.005***	-0.013***	-0.005***	-0.015***	-0.004***	-0.015***	-0.005***
	(-0.0002)	(-0.00000)	(-0.0001)	(-0.00002)	(-0.0001)	(0.00000)	(-0.0003)	(-0.00003)	(-0.0002)	(-0.00001)	(-0.0004)	(0.00001)
Population	0.999***	0.991***	0.939***	1.001***	0.977***	0.997***	0.957***	1.004***	0.966***	0.993***	0.960***	0.995***
	(0.001)	(0.0004)	(-0.001)	(-0.0001)	(0.001)	(0.001)	(-0.003)	(-0.0002)	(-0.001)	(0.0003)	(-0.002)	(0.0001)
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	687	774	687	774	687	774	687	774	687	774	687	774
R^2	0.715	0.887	0.700	0.889	0.688	0.887	0.690	0.889	0.698	0.889	0.695	0.887
Adjusted R^2	0.705	0.884	0.690	0.885	0.677	0.884	0.680	0.886	0.688	0.886	0.685	0.884

Note: *p<0.1; **p<0.05; ***p<0.01
Serial correlation and heteroskedasticity consistent robust standard errors are reported in parentheses.

Table 4.7 - Estimation results using different measures of institutional quality.

	Dependent variable: Number of people with access to electricity					
	Rural (7a)	Urban (7b)	Rural (8a)	Urban (8b)	Rural (9a)	Urban (9b)
Political rights and civil liberties	-0.041	0.001				
	(0.038)	(0.021)				
Democracy			-0.001	-0.001		
			(0.003)	(0.001)		
State fragility					-0.035**	0.002
					(0.016)	(0.008)
per capita GDP	0.524***	0.465***	0.617***	0.482***	0.298	0.491***
	(0.179)	(0.082)	(0.182)	(0.082)	(0.223)	(0.086)
Population density	0.419***	0.020	0.427***	0.014	0.384***	0.020
	(0.076)	(0.052)	(0.080)	(0.054)	(0.081)	(0.051)
Aid	-0.012	-0.004	-0.014*	-0.006*	-0.016**	-0.006*
	(0.008)	(0.004)	(0.008)	(0.003)	(0.008)	(0.003)
Population	0.976***	0.998***	0.958***	1.016***	1.050***	1.018***
	(0.069)	(0.047)	(0.074)	(0.052)	(0.091)	(0.054)
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	719	813	664	758	643	734
R^2	0.693	0.885	0.656	0.863	0.690	0.865
Adjusted R^2	0.683	0.882	0.643	0.858	0.679	0.861

Note: *p<0.1; **p<0.05; ***p<0.01

Table 4.8 - Estimation results using project level data (dependent variable: power projects to serve urban areas).

	Dependent variable: Power to urban area		
	(1)	(2)	(3)
Governance	0.055***		
	(0.727)		
Governance (3rd lag)		0.071***	
		(0.721)	
Governance (5th lag)			0.065***
			(0.725)
GDP	0.754	0.617	0.585
	(1.248)	(1.291)	(1.317)
Majority private (>50%)	3.258*	2.612	2.105
	(0.649)	(0.666)	(0.693)
Large capacity (>25 MW)	12.682***	11.226***	12.529***
	(0.633)	(0.638)	(0.654)
Installed capacity	0.537	0.592	0.617
	(0.476)	(0.485)	(0.510)
Constant	0.548	4.860	2.895
	(12.473)	(12.792)	(12.759)
Time-fixed effects	Yes	Yes	Yes
Pseudo R-squared	0.33	0.32	0.34
Chi-squared p-value	0.000	0.000	0.000
Observations	138	127	121
Log Likelihood	-59.342	-56.367	-52.086
Akaike Inf. Crit.	166.685	154.735	142.171

Note: *p<0.1; **p<0.05; ***p<0.01
All the models include year dummies.

Table 4.8 presents the results of estimating Equation (4.2) for power projects serving urban areas as the dependent variable. The main explanatory variables are governance, the third lag of governance and fifth lag of governance. The model controls for several factors. The covariates include total GDP, to account for a country's need and capacity for more power generation capacity; whether the project is majority government owned to account for for-profit motivations as opposed to expanding electricity access; the capacity of the proposed power plant as a proxy for total cost; and the installed capacity in the country. All the models include year dummies to control for innovations in financing for large infrastructure projects. Similarly, *Table 4.9* presents the results for transmission and distribution projects to urban areas as the dependent variable. In addition to the governance variables, for this estimation exercise, the covariates include per capita GDP, cost of the project, installed capacity in the country and electricity access in urban areas. In both tables, odds ratios are reported.

Table 4.9 - Estimation results using project level data (dependent variable: transmission and distribution extension to urban areas).

	Dependent variable:		
	T&D extension to urban area		
	(1)	(2)	(3)
Governance	0.109**		
	(0.889)		
Governance (3rd lag)		0.096***	
		(0.880)	
Governance (5th lag)			0.088***
			(0.848)
per capita GDP	11.676**	11.963**	17.801**
	(1.204)	(1.192)	(1.287)
Project cost	1.454	1.511	1.252
	(0.654)	(0.653)	(0.624)
Installed capacity	1.082	1.027	1.064
	(0.262)	(0.269)	(0.269)
Electricity access (urban)	0.953**	0.956**	0.954**
	(0.020)	(0.020)	(0.020)
Constant	0.0002	0.0001	0.0001
	(6.510)	(6.495)	(6.218)
Time-fixed effects	Yes	Yes	Yes
Pseudo R-squared	0.16	0.17	0.19
Chi-squared p-value	0.027	0.017	0.009
Observations	60	60	60
Log Likelihood	-34.428	-33.846	-33.099
Akaike Inf. Crit.	80.856	79.692	78.198

Note: *p<0.1; **p<0.05; ***p<0.01
All the models include year dummies.

4.6 Case studies

In this section, case studies of four Sub-Saharan African countries are presented. The case studies give context and understanding to the results of the empirical estimation in Section 4.5. The case study analysis examines the evolution of electrification with the political landscape in each country and looks at implementation of power projects. More specifically, the study primarily observes three major changes over time: the change in the funding institutions and type of funding for power projects; the change in the areas that the power projects serve; and the change in donor conditions over time.

The data used for this exercise is from a database of power projects in Sub-Saharan Africa compiled by the author from several project databases, a subset of which was used in the empirical estimation highlighted in Section 4.4.1.

The case studies are presented as follows. First, a comparison is made between Benin and Togo: two bordering countries with similar political histories up until a divergence in the early 1990's. Second, Gambia's recent electrification efforts are examined. Gambia has a historically unconventional sequence of democratic and autocratic rule within a Sub-Saharan African context. Finally, Ghana is presented as a case of good governance and good electricity access. In Figure *4.2* in Section 4.3 each country has a different trajectory within the four quadrants. Togo experiences substantive increase urban electrification during a period of steadily poor governance (moves from the middle of the bottom left quadrant in 2000 to the middle of the top left quadrant in 2018), while in Benin a moderate increase in urban electrification occurs during a period of relatively good governance (moves from just below the intersection of the axis in 2000 to just above it within the top left quadrant in 2018). In Gambia, an increase in urban electrification happened between 2000 and 2018 during a period of significant decrease in the quality of governance. Ghana, on the other hand, has maintained a relatively good level of governance during this period while experiencing small increases in urban electrification. For all four countries, the data between 2000 and 2018 do not tell the whole story. In this section, historical narratives are introduced that provide more evidence of the research proposition made in Section 4.2.

4.6.1 Divergence in governance: Benin and Togo

Benin gained independence from France in 1960. In 1963, only 3 years after independence, the independence president was ousted in a military coup. This was a followed by a series of transitory military and civilian regimes. In 1972, Matheiu Kerekou seized power and established a one-party system in 1975 with him at the helm. In similar fashion to other dictatorships, Kerekou's government was criticised for its human rights record. And in 1990, under pressure from the international community and local political opposition, the government succumbed to the outcomes of a popular referendum and agreed to hold multiparty elections under a new constitution. In the new system, the president is elected directly for a five-year term, renewable once. The new system also established independent courts. The transitional period was led by Prime Minister Nicephore Soglo. The results of the 1991 elections gave the opposition party, the Union for the Triumph of Democratic Renewal (UTRD), the majority of the seats, and their candidate, Nicephore Soglo, was elected president with 67% of the vote. The 1996 presidential elections brought back Mathieu Kerekou as president. He won the next election in 2002. In 2006, he was over 70, the constitutional age limit, and was therefore not allowed to run. The same was true for Nicephore Soglo. As a result, the 2006 elections were won by a newcomer, Thomas Yayi Boni. In the parliamentary elections, his seven-party coalition won 64 out of 83 seats.

Since the early 1990's Benin has held a succession of peaceful, relatively fair and free presidential and parliamentary elections. The most important of which was the 1991 election, which brought an opposition party to power and ensured a peaceful transition from dictatorship to multiparty democracy. Today, Benin scores relatively high in most indicators of governance. Compared to its Sub-Saharan African counterparts, it scores high in political stability, rule of law and voice and accountability. Its Freedom House score is similar to Argentina. And it has a recognised system for constitutional checks and balances, a good human rights record, and a free press. However, Benin suffers from similar problems as other Sub-Saharan African countries: there's widespread poverty and corruption. It also suffers from shortages in energy provision, with its electrification rate not far from the continental average, and widespread use of biomass as a primary source of energy.

In comparison, Benin's neighbour, Togo, also a West-African country, gained its independence from France in 1960. In 1963, a military coup ended 3 years of parliamentary democracy. A period of political instability and failed transitional governments followed, until a military coup in 1967 brought Gnassingbe Eyadema to power. For the next few decades Eyadema ruled with absolute power and, using his newly established security apparatus, banned all kinds of political activity, including political parties and civil society organisations. In the early 1990's an opportunity for reform presented itself when, during the global wave of democratisation, the Togolese government was pressured to make reforms. By 1992, political parties were legalised and constitutional reform established a presidential republic. In the elections that followed, Eyadema won as the candidate for the Rally of the Togolese People party. He then won the subsequent elections in 1998 and 2003 on the back of significant election violence, arbitrary detention of members of the political opposition, and widespread corruption.

President Eyadema died in 2005. The military quickly appointed his son, Faure Gnassingbe, as his successor. Following local, regional and global objection to the appointment, Faure Gnassingbe won the presidential election in 2005 with 60% of the vote. Large scale protests erupted in the country against the election results. The new president appointed his brother as Minister of Defence and violence followed. There were several hundred deaths and tens of thousands of Togolese fled the country to neighbouring Benin and Ghana. After the 2005 presidential election, suppression of freedom of speech became more severe: TV channels and media outlets critical of the regime were shut down, radio stations were closed, and websites blocked off.

Until 2018, Togo had one of the worst quality of governance ratings both regionally and globally. It is classified as “not free” by Freedom House and ranks amongst the worst countries in Sub-Saharan Africa in terms of accountability, regulatory quality and rule of law. The current governance system is characterised by corruption and the absolutist powers of the security apparatus. In the political science literature, Togo is considered an “electoral autocracy” (or an “illiberal democracy”, or a “competitive authoritarian regime”). This type of regime makes illusory reforms at the surface and adopts democracy-like electoral processes for the executive and legislative bodies, which are eventually rigged in favour of the incumbent. This process is meant to legitimise the absolutist rule of the regime.

Except for the different governance trajectories embarked upon by each country since 1990, Benin and Togo have many similarities and share markets and key infrastructure. Like Benin, Togo is highly dependent on electricity imports. Both countries are part of the Economic Community of West African States (ECOWAS) and the West African Economic and Monetary Union (WAEMU). Both countries are highly dependent on their neighbours for electricity imports. They import most of their electricity from Nigeria, Ghana and the Ivory Coast through the Benin-Togo utility, Communaute Electrique du Benin (CEB). Electricity imports cover 91% and 95% of Togo and Benin's consumption, respectively.

Due to increases in population and GDP, electricity consumption has increased over time for both countries. But where that electricity is consumed differs. In 1990, when political pressure brought an end to Kerekou's dictatorship and paved the way for the election the following year, Benin's urban electrification rate was around 30% and rural electrification was well under 5%. Since 1996, both urban and rural electrification have increased at similar rates, while electricity consumption continued to increase. In Togo, the international political pressure did not induce similar democratic change. Eyadema's dictatorship continued until his death in 2005 when power was handed down to his son. Since then, the quality of governance has increased only slightly. During this time, the rate of increase in urban electrification far outweighed that of rural electrification. By 2016, urban electrification was just under 90% while rural electrification was just over 20%.

The shift in electrification priorities is evident in the data, at the macro and project level. Table *4.10* shows details on power projects in the two countries. In Benin, in the period before the democratic transition in 1990 projects were mostly implemented to enhance electricity service delivery in urban areas. For the projects implemented after 2000, when the World Bank started to introduce good governance as a condition to engaging with developing countries, Benin started to receive more development financing for power projects, most of which were implemented to serve rural areas (the projects implemented in 1977, 1981 and 1991 were subjected to Structural Adjustment conditions as opposed to good governance).

In Togo, there is no evidence of a shift in priority areas for service delivery post-1990. And perhaps because of new good governance conditionalities, large projects such as the Centrale Thermique de Lome in 2008 were implemented as Independent Power Projects (IPPs). Given that democratic governments in developing countries are more likely to adopt power sector reform than non-democratic ones (Urpelainen and Yang, 2019), and in the absence of governance-conditioned finance from institutions like the World Bank, allowing private sector involvement to increase electricity access seems like a logical strategy. A similar strategy is adopted by other countries, such as Gambia (see Section 4.6.2).

Table 4.10 - Power projects in Benin and Togo (Source: multiple; compiled by the author).

Benin							
Donor	**Project name**	**Amount of finance (million $)**	**Type of finance***	**Year**	**Implementation period (months)**	**Area**	**Stringency on governance**
IDA	Technical Assistance Project	1.7	Loan (TA)	1977		Urban	No
IDA	Nangbeto	1.8	Loan (TA)	1981		Urban	No
IDA	Power Rehabilitation and Extension Project	15	Loan (IN)	1991		Urban	No
Multiple	Electricity Services Delivery Project	95.7	Loan (AP)	2004	96	Rural	Yes
Multiple	Increased Access to Modern Energy	176.7	Loan (IF)	2009	108	Rural	Yes
IDA	Energy Service Improvement Project	61	Loan (IF)	2017	78	Urban / rural	Yes
Togo							
Donor	**Project name**	**Amount of finance (million $)**	**Type of finance**	**Year**	**Implementation period (months)**	**Area**	**Stringency on governance**
IDA	Power Engineering and Technical Assistance Project	2	Loan (TA)	1981	48	Urban	
Multiple	Power Rehabilitation and Extension Project	38.5	Loan (IN)	1990		Urban	
	Togo Electricite	67.7	IPP	2000	20	Urban	No
	Centrale Thermique de Lome	196	IPP	2008	25	Urban	No
Multiple	Emergency Infrastructure Rehabilitation and Energy Project	26.8	Loan	2009	72	Urban	Yes
IDA	Energy Sector Support and Investment Project	36	Loan (IF)	2017	60	Urban	Yes

* Type of finance: TA – Technical Assistance Loan, IN – Specific Investment Loan, AP – Adaptable Program Loan, IF – Investment Project Financing, IPP – Independent Power Project.

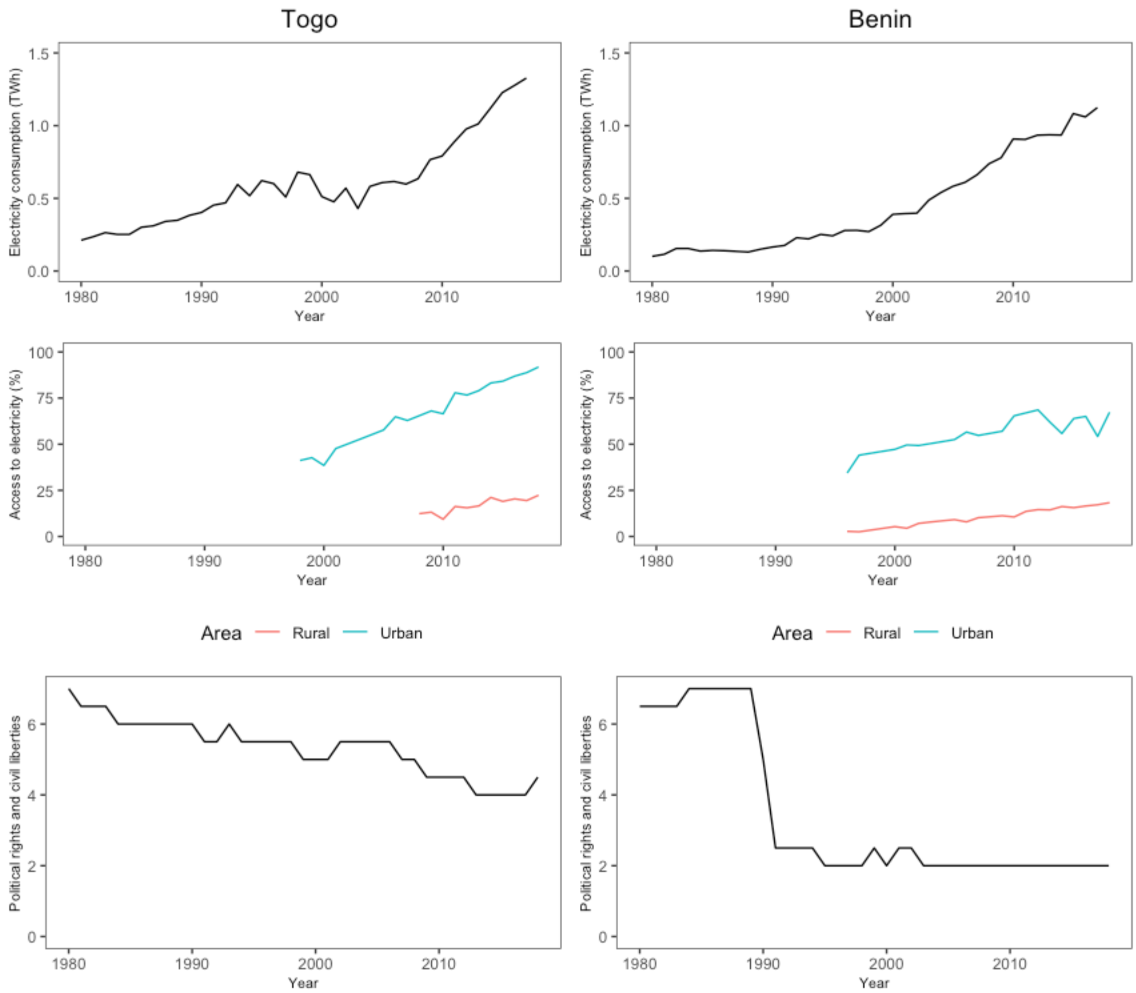

Figure 4.4 - The evolution of urban and rural electrification, total electricity consumption and political rights and civil liberties in Benin and Togo (source: electricity consumption and electrification data from World Bank (2020a), and political rights and civil liberties data from Freedom House (2018)).

At the macro-level, Figure *4.4* shows the trends in electrification, electricity consumption and institutional quality in Benin and Togo between 1980 and 2018. Both countries exhibit a consistent increase in total energy consumption during this period. Despite the limited availability of data on electricity access in the two countries, the two graphs on electricity access in Figure *4.4* show that urban electrification in Togo outpaced rural electrification, while the rates of increase are almost the same in Benin. These trends coincide with the shift to more democratic rule and better quality of governance[15] in Benin and a continuation of the status quo in Togo (two bottom graphs in Figure *4.4*), where the political rights and civil liberties rating of Benin goes from 7 to 2.5 in 1990 and remains at 2 for the remainder of the period, whereas in Togo the same quality of governance rating remains between 6 and 4 until 2018.

4.6.2 Historically different: Gambia

A former British colony, the Gambia has a peculiar political history for a Sub-Saharan African country, with the military assuming power after more than two decades of multi-party democracy post-independence. A military coup in 1994 followed 24 years of dominance by the People's Progressive Party (PPP) led by Dawda Jawara. After independence in 1970, the Gambian economy, dominated by ground nut exports, performed well and allowed the government to build up its foreign currency reserves. The economic growth did not last for long. The oil crisis of 1973 and a drought in the early 1970's dried up the government's resources. Due to increasing external debt and inflation, the Gambian government was forced to implement an economic reform structural adjustment programme in the mid-1980's to stop the economy from collapsing. One of the major reforms was a reduction in public spending, which resulted in a decrease in the quality of public services. This, along with other issues related to mismanagement, lay the foundation for the military coup in 1994.

The coup in 1994 was organised by a group of young officers led by Yahya Jammeh. Following a two-year transitional period, Jammeh, standing as a civilian, won a 1996 presidential election as the candidate for the newly formed Alliance for Patriotic Re-orientation and Construction (APRC). This was followed by election wins in the 2001, 2006 and 2011 elections. The dominance of the APRC is a direct consequence of an initial ban on political parties, the subsequent disillusionment of the opposition and general oppressive policies. The Gambia's

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[15] The measure of quality of governance used in the figure is Freedom House's two indicators: political rights and civil liberties. The y-axis of the bottom two graphs in the figure plots the average of the two indicators.

human rights record after 1994 is poor: criticism of the government was not tolerated, newspaper closures were frequent, and assassinations and disappearances became a tool of oppression. This was never an issue under Jawara's presidency between 1970 and 1994. The quality of governance decreased significantly after 1994.

The authoritarian intents of Jammeh's regime were clear from the start. There was hostility towards press freedom and journalists. Short of banning the press altogether, the new military regime drove certain publications into near bankruptcy, created and bolstered partisan state-controlled newspapers and television stations, and arrested and physically abused any journalist who was critical of the government. The Gambian judiciary was manipulated. Members of the judiciary who acted against the military regime were harassed, dismissed or retired, and replaced by more cooperative judges. New decrees were issued curbing human rights and civil liberties. The death penalty was reintroduced, and an intelligence agency was established with unlimited powers for detention and surveillance. Opposition political figures felt the brunt of this. They were harassed and detained, sometimes for long periods without charge, and were only released after elections, indirectly banning them from participating. In the meantime, corruption and political appointments became the norm, and Jammeh and his allies amassed vast amounts of wealth, until he lost the 2016 presidential election to Adama Barrow.

President Barrow, democratically elected in 2016, assumed office in 2017. This was a turning point in Gambia's political history, ending a 22-year dictatorship and reintegrating Gambia back into the international community. This was the first democratic transfer of power in Gambia's history.

Gambia's electrification history is consistent with other Sub-Saharan African countries in that until the mid-1990's the push for rural electrification was almost non-existent. Most of the electricity in the country was being consumed in urban areas, even after additions to installed capacity after 2001. Today, Gambia's total installed capacity is around 120 MW. Almost 70 MW serves the Greater Banjul Area around Banjul, the capital city, with a population of around 400,000 people (16% of the total population of), and Brikama, the second largest city. This includes the two largest power stations in the country: Kotu power station with a capacity of 25 MW, and Brikama power station with a capacity of 25 MW. The rest of the country's installed capacity is scattered around in smaller stand-alone power stations serving major provincial towns. Until 2007, the rural electrification rate was significantly lower than urban electrification rate, but the approval of the National Energy Policy in 2005 and the launch of the Rural Electrification Project in 2007 shifted some of the government' focus towards rural electrification. Electrification slightly improved in some localities, with 6 hours of electricity in the morning and 6 hours in the evening. Throughout Gambia's history, the National Water and Electricity Company (NAWEC) monopolised generation, transmission and distribution of electricity. The monopoly ended in 2006 with an independent power project (IPP) commissioned to provide 26 MW of electricity in Brikama, an urban area.

The last decade saw a significant shift in the political climate. The first half was dominated by Jammeh's brutal dictatorship, until Adama Barrow won the 2016 presidential election. Barrow's presidency today is regarded as a success, and Gambia's quality of governance indices have reflected that. There have been significant increases in quality of governance with regards to voice and accountability, rule of law and control of corruption. This change can also be seen in Gambia's dealings with the world.

Most notably, this change has had a noticeable effect on the type of support available to Gambia from international financial institutions (IFIs) for large infrastructure projects. More specifically, power projects seem to reflect the restrictions on the government and government priorities, depending on which IFI is providing the finance, the type of finance and area served by the project are different before and after 2016. Before 2016, two projects on power generation and expansion were financed by the Islamic Development Bank (IDB) and Exim Bank of India, respectively, and both were mostly loans (a small part of the IDB's finance was a grant) (Table *4.11*). The two financing institutions, one a regional IFI and the other a national one, have no compliance criteria regarding quality of governance. Both projects were planned to serve urban areas.

After 2016, the type of financing available to the government of Gambia changed, and so did the projects. First, all three projects initiated after 2016 included grants. The Scaling up Renewable Energy Programme (SREP) provided a grant to support a green mini-grid programme. The two World Bank projects include grants: one third of the financing for the Gambia Electricity Support Project is a grant; all the finance for the Gambia Electricity Restoration Modernisation Project is a grant. Second, two of the three projects have a rural electrification mandate. Third, the type of financing made available after 2016 makes sense because of the World Bank's stringency on governance. Lastly, after 2016, the government was able to secure financing for projects with longer implementation periods. This reflects both the reduced risk perception and the type of financing available before 2016.

Table 4.11 - Power projects in Gambia (Source: multiple; compiled by the author).

Donor	Project name	Amount of finance (million $)	Type of finance	Year	Implementation period (months)	Area	Stringency on governance
IDB	Birkama II 20MW Power Supply Project	24	Grant/loan	2011	24	Urban	No
Several	OMVG (includes Senegal, Guinea and Guinea-Bissau)	722	Loan	2015	84	Urban	No
Exim Bank of India	Electricity Expansion Project	22.5	Loan	2015	18	Urban	No
World Bank	Gambia Electricity Support Project	18.5	Grant/loan	2016	60	Urban	Yes
SREP	Green mini-grid country support program	1	Grant	2017	24	Urban / rural	-
World Bank	Gambia Electricity Restoration Modernisation Project	41	Grant	2018	60	Urban / rural	Yes

Moreover, the World Bank's risk assessment for projects reflects the organisation's insistence on attaching governance conditions on its loans and grants. There are obvious differences in the language used in the project appraisal documents of the project in 2016 (the risk assessment for which was done before 2016) and the project in 2018 (Table *4.12*). For example, for both projects, the political and governance risk assessment admits that progress has been made, but that progress is "mixed" for the 2016 project. This makes sense even if the risk assessment was updated after the transfer of power because of possible spill overs from the previous regime. The risk mitigation is also different. For the 2016 project, the document highlights that risk is partly mitigated because of the government took the bank's advice on certain changes. For the 2018 project, on the other hand, risk mitigation is linked to independent reforms by the government, such as "high-level" commitment to the energy sector and restructuring of NAWEC's board. And although the macroeconomic risk is considered high for both projects, the mitigation for the 2018 project acknowledges that the government is committed to economic reforms that the bank considers appropriate. Also, the assessment highlights that the new government was making progress in enhancing governance, accountability and transparency in the public sector and state-owned enterprises. It is also important to point out that the World Bank provided some of the financing for the Gambia River Basin Development Organisation Energy Project (OMVG Energy Project) before 2016, but that was considered low risk because of the involvement of other countries, mainly Senegal, Guinea and Guinea-Bissau.

Table 4.12 - World Bank project appraisal for power projects before and after the democratic transformation in Gambia (Source: World Bank project documents).

Project	Year	Area	Type of financing	Project appraisal
Electricity Support Project	2016	Urban	Grant/ loan	**Political and governance risk: High.** NAWEC is exposed to high political and governance risk. But the government has made progress, albeit mixed, with the introduction of some reform measures to define institutional arrangements that enhance transparency and accountability in public sector procedures. **Mitigation**: the risk is partly mitigated through recent changes suggested by the WB financed Energy Sector Road Map, which includes the appointment of an internal audit committee and other positions. **Macroeconomic risk: High.** Risks derive primarily from persistent fiscal and exchange rate policy slippages that have contributed to a significant rise in government borrowing interest rates with heightened investor uncertainty, a build-up in public sector debt and weak GDP growth outturns. In the absence of implementation of comprehensive macroeconomic policy reforms, the government faces a possible forced adjustment. NAWEC is exposed through imported fuel and

				spare parts and other purchases whose costs are highly dependent on the exchange rate. **Sector strategies and policies risk: High.**
Electricity Restoration Modernisation Project	2018	Urban/ rural	Grant	**Political and governance risk: High.** NAWEC is exposed to high political and governance risk. But the government has made progress with the introduction of fiscal stabilisation programs and reform measures to enhance transparency and accountability in public sector procedures. **Mitigation**: the risk is partly mitigated through the introduction of a competitive HFO fuel supply and update Energy Sector Road Map. The high-level commitment of the government to the energy sector, and the new NAWEC board appointed in 2017 will also mitigate the risk. **Macroeconomic risk: High.** Downside risks remain high at this point in Gambia's transition. Enormous investments in infrastructure and human capital are needed to unleash the growth potential. Mitigation: the government is committed to proactive debt restructuring with the support of development partners, fiscal discipline, reducing the reliance on domestic financing and a flexible exchange rate regime. **Sector strategies and policies risk: Substantial.**

4.6.3 Good governance, good access: Ghana

Here, Ghana is used as a case study of good governance and good access. But most importantly, how Ghana got to where it is today is of interest. Ghana's electrification story embodies the hypotheses presented in this chapter.

In 1992 Ghana held its first multiparty elections since the elections of 1979. The elections were overseen by the government of Jerry Rawlings, a military man and Ghana's Head of State between 1981 and 1993. Jerry Rawlings' National

Democratic Congress (NDC) won. The elections were considered fair by international observers despite the opposition boycotting the parliamentary elections. The next elections in 1996, this time considered even fairer than in 1992, were again won by the NDC. In 2000, the candidacy of the NDC was given to John Atta Mills when Rawlings' term expired.

During the first decade of electoral politics in Ghana, voting patterns were relatively stable (Briggs, 2012). The NDC was more popular in rural areas, and the main opposition party, the NPP, secured the urban vote. The NDC's popularity in poor and rural areas was partially due to its extension of infrastructure and social services to marginalised areas around the country. There is evidence that the NDC scheduled infrastructure projects to be implemented just before elections. Bawumia (1998) finds that the provision of infrastructure services in rural areas were crucial for the NDC's 1992 election win. Similarly, Nugent (2007) argues that the scheduling strategy also helped determine the outcome of the 1996 elections. The use of electrification as a tool for vote buying is evident in the sudden and continued increase in rural electrification, which increased from 3% in 1993 to 20% in 2001.

Before the elections, between 1983 and 1992, Rawlings' government experimented with several political control strategies. In his first year, Rawlings quickly established his strongman reputation through executions and human rights violations in the political arena. During this time, in Sub-Saharan Africa, labour unions yielded considerable political power. Labour was politically powerful for two reasons: labour was concentrated, as opposed to the scattered nature of the rural poor population; and labour is in the cities, which means it poses the biggest political threat through organised protests. At the time, in most Sub-Saharan African countries, the power of the government was highly dependent on its ability to control the cities, especially the capital. Recognising this threat, Rawlings' government, upon assuming power, replaced the union leadership with government supporters. This move, in addition to the repression tactics, helped the government avoid large scale protests after an increase in prices due to a new Economic Recovery Programme (ERP) in 1983. The government's ERP of 1983 was implemented under the auspice of the International Monetary Fund (IMF) and the World Bank. In addition to outlining fiscal and social policies for the government to follow, the ERP included a rehabilitation of existing infrastructure to improve economic productivity. Infrastructure investment included electricity, water supply and roads and bridges, all aimed at extending these services to the rest of the country. However, because the rehabilitation efforts were part of the ERP, priority was given to areas producing commodities for export. As a result, rural areas in Northern, Upper East and Upper West regions did not benefit (Bawumia, 1998). Furthermore, the urban lens through which Ghanaian politics operated at the time, made representation of the rural population almost impossible. The institutions necessary to allow rural representation in the economic and political debate did not exist. The coups that followed a succession of democratic failures between independence in 1957 and 1983 led to a deterioration of the country's administrative system, which further alienated the rural population.

This reality did not change under the Rawlings regime. Because of the way they assumed power, the government leadership focused its efforts on appeasing the urban population. The link with the rural population was further undermined by the lack of political legitimacy of the new government (it didn't come through the ballot). It was not helpful that economic growth was predominantly associated with industrialisation in urban Ghana. Even the pro-agriculture policies of 1983, which were designed to increase cocoa production, the country's main export crop, were not intended to benefit the rural poor. As part of the ERP, the IMF's emphasis on the current account imbalance put pressure on the government to revive the cocoa industry. This had two major consequences: the rural poor did not immediately benefit because cocoa trees take several years to produce; other food crops were neglected, which means those who do not plant cocoa don't have an increased income to look forward to. Because of the prioritisation of certain areas for infrastructure rehabilitation and service provision, a large number of rural towns and villages were not connected to the grid and major road network, and the ones that did get connected had to wait until the early 1990's (Bawumia, 1998). This meant that the rural populations that produced food crops other than cocoa did not benefit from neither government support for agriculture nor new infrastructure. At the time, the overwhelming majority of the population did not have access to electricity. They were also not likely to have political representation. But for those who benefited from the new policies, they saw government in a new light.

The infrastructure extensions that were part of the ERP benefited Rawlings' presidential bid in 1992. Despite the argument put forward by Nugent (2001, 2007), it's also likely that, in 1992, the political support that Rawlings received due to the infrastructure investments in the previous decade was more chance than design. Mainly because infrastructure projects take a long time to materialise. So, the infrastructure extension in the early 1990's would be attributed to the ERP, not necessarily just the NDC's electoral strategy. But in 1996, infrastructure provision was a clear re-election strategy (Briggs, 2012). By 1996, Rawlings' government had made significant improvements to the country's infrastructure, especially in the productive, rural parts of the country. Infrastructure investments were funded using development aid, and, hence, the NDC gained a reputation of allocating aid money to infrastructure investment that help its presidential bid. In 1997, aid accounted for around 50% of total investment in the country (Leite *et al.*, 1999). For the 2000 election, the NDC tried to stick to the same strategy. It failed for two main reasons: the decrease in the price of cocoa and increase in the price of oil caused a trade imbalance; the government received less aid than it anticipated and less than the previous year (World Bank, 2020). The decrease in aid caused a similar decrease in service provision. This time round, when the elections came, the NDC didn't have much to brag about.

The link between electrification and votes in the 2000 election in Ghana was studied by Briggs (2012). The author finds that the NDC used the National Electrification Project (NEP), a World Bank funded programme that aimed to increase electrification, to attract more votes in certain constituencies. The NEP was agreed upon after the 1992 elections. The constituencies that were chosen to receive electrification as part of the NEP were areas where the NDC had a majority vote in 1992. With that, Briggs (2012) concludes that regional level data shows a clear targeting strategy: electrify the pro-NDC constituencies. Comparing two constituencies, one selected for the NEP and one not selected, Briggs (2012) finds a clear divergence in voting behaviour between the two constituencies between 1996 and 2000. This can be attributed to inclusion in the

NEP because there is very little divergence between the same two constituencies during the period 1992 to 1996 and 2000 to 2004, when there weren't electrification expansion efforts. Infrastructure service expansion, initially part of the ERP with a clear goal of increasing productivity before 1992, became a vote-winning strategy.

The use of electrification for political gain can also be seen in how electricity access evolved over time in Ghana (Figure *4.5*)[16]. In 1993, one year after the advent of electoral politics, there was a significant difference in electrification rates between rural and urban areas. Since then, electrification has increased for both rural and urban areas, with a more dramatic increase in rural areas – 8% in 1991 to 67% in 2017 – than in urban areas – 74.6% in 1993 to 90% in 2017. There are potentially several explanations for the unprecedented increase in rural electrification, including more emphasis on electrification from donors and multilateral organisations, more room for improvement in rural areas than in urban areas, and a general push to increase access to modern energy as part of the global climate change agenda. But the democratic transformation seems to have an effect. In Figure 4.5, the rate of electrification in Ghana is compared to Kenya, which experiences a similar increase in rural electrification, but only after 2000, when there was a demonstrable betterment in the quality of governance.

Given the historical and political context summarised above, it is important to note the electrification rate at the beginning of the democratic period. In 1991, only 8% of the rural population had access to electricity, while 75% of the urban population had access to electricity. Considering the ERP adopted in 1983, and the emphasis on infrastructure investment, it seems most of the electrification efforts of the decade before the 1992 elections were mostly in urban areas. This makes sense, since at the start of Rawlings' grip on power in 1981, when there were no elections and the only threat to power was from popular protests, the urban base was the most politically powerful. Towards the end of the 1980's, whether through exhausting whatever political tools were at the government's disposal or because

[16] The measure of quality of governance used in the figure is Freedom House's two indicators: political rights and civil liberties. The y-axis of the bottom two graphs in the figure plots the average of the two indicators.

of the ERP infrastructure investments finally bearing fruit, rural electrification increased by 50% between 1988 and 1991 from 5% to 8%. This was followed by a consistent increase in rural electrification throughout the 1990's, 2000's and 2010's. This change is also evident in the power projects in Ghana before and after the democratic transformation (Table *4.13*).

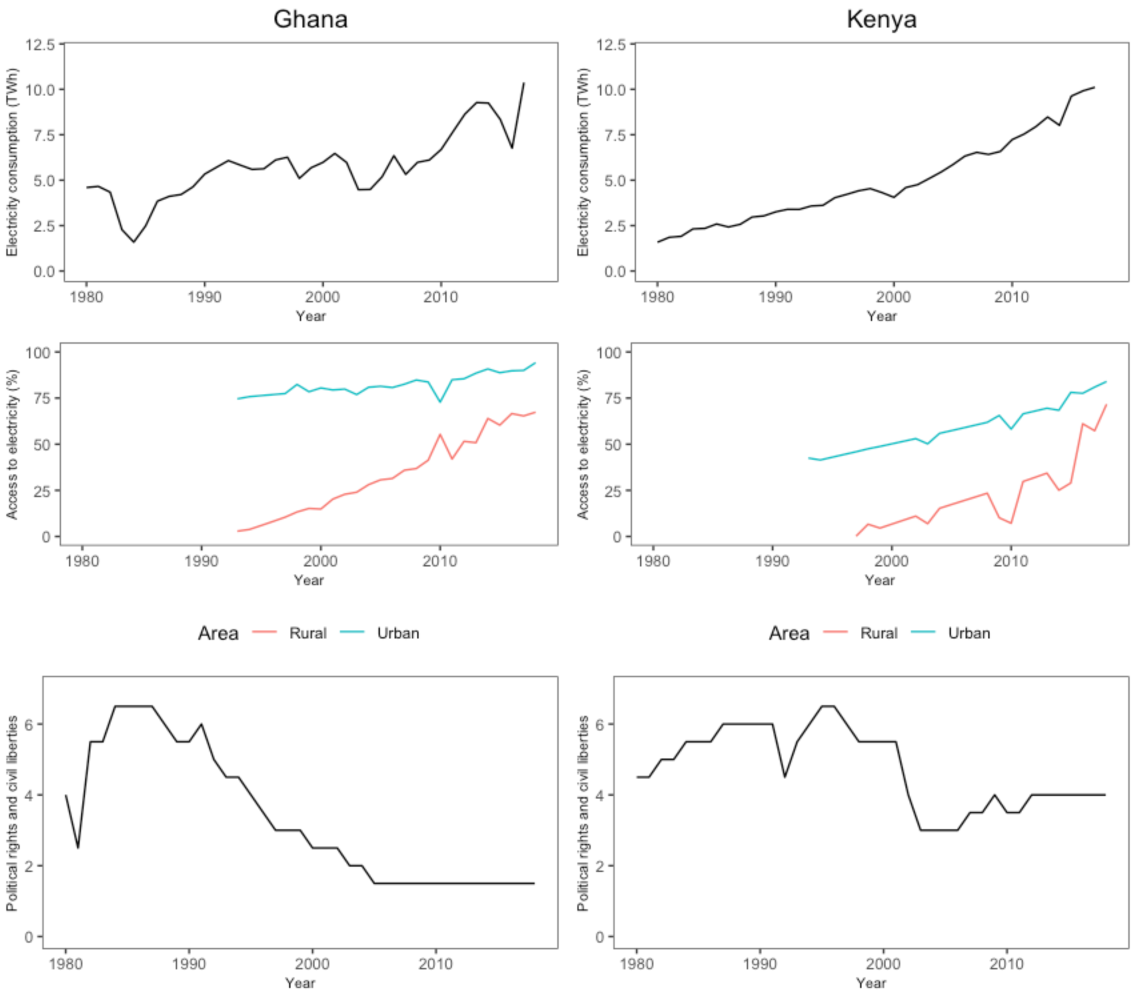

Figure 4.5 - The evolution of urban and rural electrification, total electricity consumption and political rights in Ghana(source: electricity consumption and electrification data from World Bank (2020a), and political rights and civil liberties data from Freedom House (2018)).

Before 1992, most of the power projects were implemented to electrify urban areas (Table *4.13*). Soon after, more effort was put into electrifying rural areas, especially as part of the NEP. Most of the electrification efforts in the 2000's were aimed at rural areas; some were designed to increased electrification in both rural and urban areas. The use of Independent Power Projects (IPP's) in the late 1990's gave the government another option of financing infrastructure extension. Instead of just using development aid and public moneys to finance electrification projects, the private sector was now able to help solve the electrification problem. After the World Bank's strategy on energy in developing countries switched from power sector reform to rural electrification in the mid 1990's (Cook, 2011) and, soon after, its loan conditionality switched from structural adjustment to quality of governance, Ghana was eligible for a lot of financing for its electrification efforts. Despite that, after 2000, there was significant increase in the number of IPP's. Being more expensive, and having no quality of governance requirements, IPP's were an obvious choice for increasing access to electricity in urban areas.

Having said that, 3 out of the 11 IPP's implemented after 2000 were for increasing rural electrification. The benefits of using IPP's for rural electrification are not immediately obvious. For example, power generated by IPP's are sold to the government under 25-year power purchasing agreements (for example, Takoradi 2 Power Plant). The government then sells the electricity to its rural (and urban) customers. Given that purchasing power in rural areas is significantly lower than in urban areas and the geographical distribution of rural towns and villages, it is much more expensive electrifying rural areas. To a certain extent, if rural households cannot pay the tariff set in the power purchasing agreements, the government will have to introduce a subsidy. This expensive and resource intensive endeavour has only one immediate benefit to the government: rural votes.

Table 4.13 - Power projects in Ghana (Source: multiple; compiled by the author).

Donor	Project name	Amount of finance (million $)	Type of finance*	Year	Implementation period (months)	Area	Stringency on governance
IBRD	Volta Power Project	47	Loan (IN)	1962	-	Urban	No
IBRD	Volta Expansion Project	6	Loan (IN)	1969	48	Urban	No
IBRD	Kpong Hydroelectric Project	39	Loan (IN)	1977	60	Urban	No
IDA	Sixth Power Project	146.6	Loan (IN)	1990	96	Rural	No
Multiple	National Electrification Project	134.8	Loan (SI)	1993	84	Urban /rural	Yes
Multiple	Thermal Power Project	414.3	Loan (IN)	1995	120	Urban	Yes
	Takoradi 1 & 2	110	IPP	1999	25	Urban /Rural	No
	Sunon-Asogli Gas Fired Power Plant	200	IPP	2007		Urban	No
	Osagyefo Power Barge	100	IPP	2007	20	Rural	No
Multiple	Energy Development and Access Project (GEDAP)	210	Loan (IF)	2007	180	Rural	Yes
GBOPA	Solar PV Systems to Increase Access to Electricity Services	4.4	Loan (IN)	2008	72	Rural	Yes
	Tema Osonor Plant Limited	140	IPP	2009		Urban	No
IDA	Additional Financing for GEDAP	77	Loan (IN)	2010	77	Urban /Rural	Yes
	Sunon-Asogli Gas Fired Power Plant	360	IPP	2011		Urban	No
	Takoradi 2	440	IPP	2012		Rural	No
	Takoradi 2 Thermal Power Expansion	440	IPP	2013		Urban /Rural	No
	Kpone Independent Power Project	900	IPP	2014		Urban	No
IDA	Additional Financing for GEDAP	60	Loan (IF)	2015		Urban /Rural	Yes
	Amandi Energy Power Plant	552	IPP	2016		Rural	No
	Karadeniz Powership Osman Khan		Rental	2017	10	Urban	No
	Bridge Power CCGT Power Plant	953	IPP	2019	20	Urban	No

* Type of finance: TA – Technical Assistance Loan, IN – Specific Investment Loan, AP – Adaptable Program Loan, IF – Investment Project Financing, IPP – Independent Power Project. SI – Sector Investment and Maintenance Loan.

4.7 Discussion

All six of the World Governance Indicators have a negative and significant relationship with urban electricity access. On the other hand, all six indicators have a large positive impact on rural electricity access. The magnitude of the impact varies across indicators. The coefficient of the Control of Corruption indicator is the largest in magnitude. The Political Stability indicator has no significant impact on rural electricity access. Unsurprisingly, the per capita GDP variable has a positive and significant impact on urban and rural electrification in all models, where a 1% increase in per capita GDP increases rural electricity access by 0.37% to 0.56% and increases urban electricity access by 0.46% to 0.5%. Moreover, the population density variable has a positive and significant impact on both urban and rural electricity access. Its impact on rural access is significantly higher than its impact on urban electricity access. This makes sense since urban areas, by design, have high levels of population density. The negative sign of the aid variable is consistent with the literature (see, for example, Trotter 2018). The population variable is highly correlated with both country fixed effects and the dependent variable; therefore, no inference will be made based on its coefficient. Its inclusion in the model is to account for the fluctuations in the dependent variable across countries.

The results of the robustness estimations in *Table 4.7* show similar results for the covariates. The governance indicators used for robustness have inverted scales: a higher value indicates worse quality of governance. The values are smaller because the indicators have a wider range than the World Governance Indicators used in the original estimation. The Political Rights and Civil Liberties indicator and the State Fragility indicator both show a positive relationship between governance and rural electricity access and a much smaller negative relationship between governance and urban electricity access. Only the coefficient for the State Fragility indicator on rural electricity access is statistically significant. The covariates show similar impacts as the original estimation.

Table 4.8 shows the result of estimating Equation (4.2) where the dependent variable is a dummy taking the value of 1 if a power generation plant is built to supply electricity to an urban area, and 0 otherwise. The governance variables are an average of the six World Governance Indicators. The coefficients reported are odds ratios. The coefficient of the governance variable shows that the probability of a power project being implemented to serve an urban due to a 1-point increase in quality of governance on the governance scale[17] is just 5.2%. Similarly, third and fifth lags of governance, the probabilities are 6.6% and 6.1%,

[17] From -2.5 to 2.5.

respectively. The coefficient of the GDP variable is less than 1, which means that a higher GDP is correlated with a higher likelihood that new power plants are constructed to serve rural areas. Similarly, the coefficient for installed capacity shows that the higher the installed capacity the less likely new projects are constructed to serve urban areas. On the other hand, larger projects and projects with majority private ownership are much more likely to serve urban than rural areas. This makes sense since urban demand is generally higher. And because urban incomes are relatively higher, more people can afford to consume electricity, which is a much safer revenue stream for investors. This provides evidence in support of why innovations such as the anchoring models for rural electrification exist.

Table 4.9 shows the results of estimating Equation (4.2) where the dependent variable is a dummy taking the value of 1 if a project extends transmission and distribution to an urban area, and 0 otherwise. Again, the three governance variables show that increases in the quality of governance reduce the likelihood electricity being extended to serve urban areas. Surprisingly, an increase in per capita GDP is associate with a very large increase in the odds of extending electricity to serve urban areas. The coefficients of the project cost and installed capacity variables show a positive association but are not significant. The coefficient of the urban electricity access variable shows that a 1 unit increase in urban electricity access (a 1% increase in urban electricity access) reduces the odds of a T&D project extending electricity to serve an urban area by just under 5%. This makes sense because as electrification increases in urban areas, governments are more likely to electrify rural areas in new extension projects. From all the models in *Table 4.8* and *Table 4.9*, the significance of the lagged governance variables show that quality of governance affects which areas get access to electricity today and in the future.

The case studies provide more nuanced evidence of the relationship between governance and electricity access in Sub-Saharan Africa. Benin and Togo have similar political, cultural and economic histories. But the two countries went down different governance paths in 1990, with Benin adopting a more democratic form of governance while the autocratic regime in Togo persisted. After 1990, there is a clear shift in Benin’s electrification priorities. This is evident in Figure 4.4, where significant increases in rural electrification start in the mid-1990s and keep up with increases in urban electrification. For Togo, the rate of increase in urban electrification is higher than for rural electrification for the same period. The shift in priorities is also evident in the areas served by new power projects. There is a clear shift in target area from urban to rural after democratisation in Benin, but not in Togo

Gambia’s case shows the switch in electrification priorities from urban to rural areas following a transition of power from autocratic to democratic rule. It also shows that the drive for rural electrification reflects both government priorities and funding constraints. After 2016, Gambia was able to access financing from the World Bank, which, in addition to its stipulations on quality of governance, supports rural electrification efforts. Before 2016, the Gambian government’s electrification drive was mostly aimed at satisfying urban demand, for which it sought financing from banks with less stringency on quality of governance. Therefore, Gambia’s case shows that even under international financing regulations dominated by a push for better quality of governance, autocratic governments prioritise urban electrification and can find ways to finance it.

Finally, the Ghanian case embodies the hypothesis of this chapter. In 1993, one year after the advent of electoral politics, there was a significant difference in electrification rates between rural and urban areas. Since then, electrification has increased for both rural and urban areas, with a more dramatic increase in rural areas – 8% in 1991 to 67% in 2017 – than in urban areas – 74.6% in 1993 to 90% in 2017. Considering the ERP adopted in 1983, and the emphasis on infrastructure investment, it seems most of the electrification efforts of the decade before the 1992 elections were mostly in urban areas. This makes sense, since at the start of Rawlings’ grip on power in 1981, when there were no elections and the only threat to power was from popular protests, the urban base was the most politically powerful.

The empirical results and case studies presented in this chapter provide evidence in support for the proposition made in Section 4.2, that knowing democratic governments are subjected to electoral constraints and public service provision is one way of securing votes and electricity is an effective and verifiable public service, and considering that in Sub-Saharan African countries, most the population is rural and poor, democratic governments will prioritise rural electrification. On the other hand, autocratic governments are not constrained by elections and since urban residents pose the biggest political threat to autocratic governments and because electricity is a useful political tool, autocratic governments prioritise urban electrification.

Democratic governments prioritise rural electrification, while non-democratic governments, not constrained by votes, prioritise urban electricity access. Non-democratic governments can satisfy urban electricity needs through subsidies, a cheaper option than grid expansion. Non-democratic governments can, from time to time, afford large scale electrification projects that serve a dual purpose: provide electricity to urban residents and provide a mechanism through which the government can reward its supporters. So, it can be argued that, should democratic governments act “non-democratically” and prioritise urban electrification, which has the potential to induce economic growth, rural electrification will eventually be achieved as a by-product of that growth. Expanding utilities to serve urban areas under a democratic regime with better quality institutions is likely to be more efficient than under a non-democratic authority, because, among other things, corruption decreases the efficiency of public utilities. Under the control of a democratic government, utilities will run more efficiently and play their role in powering economic growth.

The arguments made in Sections 4.1 and 4.2 suggest that because of autocratic governments’ neglect of industry and inefficient electricity distribution, an increase in the urban population in countries with authoritarian governments concerned with short-term priorities of urban power provision will only hinder efforts towards universal electricity access. Urbanisation puts pressure on urban electricity access. Urban areas are the centre of economic activity. Democratic governments, from time to time, should act non-democratically to deal with the inevitable surge in urban electricity demand. The caveat here, of course, is that democratic governments working in favour of urban electricity demand should consider the needs of all urban residents, not just the ones that pose a political threat, poor households and slums included.

5 Chapter 5: Government policy and electricity access

5.1 Framing

The results of the previous chapter, using macro and project level data and supported via in-depth case studies, show evidence of a positive relationship between governance and rural electricity access and evidence that more autocratic governments prioritise urban electrification. The motivation for investigating this relationship is the different relationship between governance and urban electricity access across countries through time. The limitations of using macro level data are well established, and the general sentiment in the literature on using governance variables in empirical analyses is that there is potential bias because of the way most indicators are created. Therefore, a more contextual understanding of the processes that drive electricity provision can help shed some light on the multidimensionality of how people get access to electricity. To do that, noting that Chapter 3 argues that electricity access rather than consumption is more important in the Sub-Saharan African context, this chapter looks at a case where rapid increases in both urban and rural electrification were achieved in line with significant progress in the quality of governance. More specifically, this chapter investigates how Rwanda's settlement policy, dictated by its political reality, affected household electricity access. Through this, this chapter aims to show that, despite evidence at the aggregate level of the motivations of autocratic governments to electrify urban over rural areas, country context matters. And that, in addition to broader governance structures, the type and quality of government policy is critical.

5.1.1 Background

Rwanda is a small, landlocked country in Sub-Saharan Africa. It shares a border with the Democratic Republic of Congo to the West, Uganda to the North, Tanzania to the East and Burundi to the South. Rwanda has 12.3 million inhabitants and a population density of 535 inhabitants per square kilometre (World Bank, 2020a). Rwanda's economy is dominated by agriculture the sector, which employs three quarters of the 6.4 million strong labour force (World Bank, 2020a). The agricultural sector accounts for a third of the total GDP, industry 16% and services over 50% of GDP (World Bank, 2020a). Rwanda is, by most measures, a poor Sub-Saharan African country, with a dominant agricultural sector, a large rural population and high poverty rate. But it has made significant strides in the last two decades. Nominal per capita GDP in 2019 was $825, a significant increase from $200 in 2000. The economy grew by 10% in 2019 (World Bank, 2020a). This progress is also seen in the electricity sector. Access to electricity increased significantly in the last decade, from 10% in 2010 to 43% in 2018 (Koo *et al.*, 2018a). The same is true for other sectors.

The economic growth of the last two decades, however, has increased the demand for land (Baffoe *et al.*, 2020). Demand for agricultural exports has led to intensive land use. This led to land being constantly divided, which means smaller and smaller land holdings (Ngoga, 2015). Despite the large number of people working in the agricultural sector, efficiency is still low. Furthermore, the majority of rural residents live in scattered housing, which further exacerbates efficiency in land use.

5.1.2 Human settlement in Rwanda

Rwanda is a small, mountainous country with a high population density and a historic emphasis on agricultural expansion for food security. Until 2004, the lack of a coherent policy to address issues of human settlement has resulted in an increase in unplanned residential areas in both rural and urban areas (van Leeuwen, 2001). The genocide of 1994 made matters worse (Kabeera and Sewpaul, 2008). The destruction of homes and a mass exodus left a lot of Rwandans and returnees homeless. To reverse this trend, the government designed a resettlement programme where residents are grouped into areas with good quality public services, access to markets and agricultural land (Ministry of Infrastructure, 2009). The new settlements centres are called “Imidugudu”.[18] The idea is to leverage the clustering of households to lower the cost of extending

[18] Imidugudu is the plural of the singular “Umudugudu.”

services to rural areas. For example, it is better use of public funds to extend the grid to an area with more demand for electricity. The programme aims to provide areas with better access to water and electricity, a clean environment, health services, and law and order (Ministry of Infrastructure, 2009). The ultimate goal of the programme is to solve the land scarcity issue and to enhance wellbeing.

The effect on wellbeing has been largely positive. There is overwhelming positive feedback on the benefits of living in Imidugudu centres, with many residents claiming to have experienced an increase in wellbeing and are hopeful of better life prospects in the future (Ngoga, 2015; Ezeanya-Esiobu, 2017). One recurring criticism is that residents of these resettlement centres are too dependent on the government for the provision of general services and infrastructure, that residents should take responsibility for providing some of the public services and that there needs to be local buy-in at all levels and from all stakeholders (Goodfellow, 2014). For the purpose of this thesis, these political arguments will not be considered. The analysis will consider the government's resettlement programme as a social and developmental policy.

The issue of land scarcity was worsened by the political unrest in the country leading up to the genocide in 1994. Over the years, the unstable political situation in the country created mass migrations and internal displacement (Ministry of Infrastructure, 2009). After the genocide, many refugees returned to find their land was either occupied or given to someone else (Takeuchi and Marara, 2009). As a temporary solution, the government of Rwanda introduced the villagisation programme (Umudugudu) along with a land-sharing programme (Hilhorst and van Leeuwen, 1999). The land sharing programme was for returnees who found their land occupied. The programme requires returnees share the land with the new owners. The villagisation programme grouped households into areas where each household was given a plot of land to farm. This, the government argued, would encourage households to work and trade with one another (Ministry of Infrastructure, 2009). The government hoped that, over time, these villages would develop into urban centres. Despite the benefits reported by residents, today, the government is facing some challenges in realising the long-term effects of the villagisation programme.

Beyond the realisation of the government's ambitions, this thesis is ultimately concerned with the impact of the villagisation programme on public service provision. More specifically, this chapter investigates whether residents of Umudugudu are more likely to have access to grid electricity than residents of unplanned rural and urban areas. One of the goals of the villagisation policy is to enhance public service provision to rural residents through clustering. Of all public services, provision of grid electricity can be made much more affordable with clustering. For example, the government can tailor classroom sizes to the number of children in a given community regardless of its size, but it's hard to justify extending the grid to provide electricity to a community with only 10 households. And because the villagisation programme is government designed, administered, and run, public service provision, such as access to grid electricity, in programme run areas should, in theory, be better than in unplanned clustered areas.

5.1.3 The development of human settlement in Rwanda

In the pre-colonial era, human settlement was based on agricultural and pastoral activity. Families lived at the centre of their plot of land, which made cultivation and harvesting easier. Colonisation introduced urban areas, which were the natural evolution of areas where people clustered, and population density was relatively high (Ministry of Infrastructure, 2009). This clustering happened mostly where locals employed by the colonial administration lived and around places of worship and business centres. At the end of the colonial period, three types of settlements emerged: pre-colonial and colonial settlements, modern urban settlements, and settlements in small business centres.

After independence in 1962, Kigali was established as the capital city and the main urban centre. The extension of infrastructure and other public services in urban centres attracted labour from rural areas. This caused an increase in demand for housing. Government planning and development of land could not keep up (Hilhorst and van Leeuwen, 1999; van Leeuwen, 2001). Low-income households, with not much choice, settled in unplanned urban residential areas. In rural areas, the first attempt by the government to create rural clustered settlements was in 1978. These first efforts failed because of lack of investment in infrastructure and lack of supervision (van Leeuwen, 2001).

After the genocide of 1994, there was a sudden increase in the need for land to house the large number of returning refugees (old refugees from previous conflicts and new ones), in urban and rural areas (Takeuchi and Marara, 2009). The need to house the large number of returnees, the large number of poor households and land scarcity put pressure on the government. In 1996, the government adopted a policy on regrouped settlements, called “Imidugudu” in rural areas. The policy was centred around creating planned rural settlements and restricting unplanned urban residential areas. In rural areas, the general mandate was to find housing for households that were homeless, poor, or vulnerable. For urban areas, a presidential order in 1997 required that construction of housing and extension of infrastructure services to unplanned residential areas (Ministry of Infrastructure, 2009). This was supported by the decentralisation policy of 2001 which required that these services also be extended to all urban centres around the country.

In 2004, the government of Rwanda enacted the National Human Settlement Policy (Ministry of Infrastructure, 2009). This new policy was designed to be in line with Rwanda’s Vision 2020. With regards to urban and rural settlements, the policy addresses the following: restructuring of grouped settlements in urban areas; creation of the Rwanda Human Settlement Bank; rehabilitation of old resettlements and unplanned residential areas. This new policy was also in line with Rwanda’s national poverty reduction strategy and considered the decentralisation policy of 2001 (UNDP, 2015).

5.1.4 The different habitats

Following the development of settlements over time in Rwanda, today, there exist several types of habitats. Some habitats are spontaneous, others, such as those created by resettlement programmes, are created by the government. In the updated National Human Settlement Policy of 2009 (Ministry of Infrastructure, 2009), the government defines settlement, Umudugudu and rural area as follows:

- A settlement is when households populate an area in groups. There are two types of settlements: rural and urban. They are distinguished by the physical characteristics of the area and activities of the resident population
- An Umudugudu is a mode of planned settlement in a rural area with 100 to 200 houses in plots of land ranging from 10 to 20 hectares, that are extendable. The settlement also provides areas for non-agricultural, commercial activities.
- A rural area is defined by its geographical location and the activities carried out by residents, such as farming and livestock. The area is usually populated by low rise houses in small numbers surrounded by large agricultural land.

In Rwanda, there are four main types of residential areas: clustered (or grouped) rural settlements, isolated rural housing, spontaneous unplanned urban housing, and planned urban housing. From these, there are six types of habitats for private households (NISR, 2014), and this is the categorisation that will be used in this chapter:

- Isolated rural housing – these are dispersed rural communities with low population densities and no government planning.
- Unplanned clustered rural housing – these are areas with grouped housing, not planned by the government, where residents live in low-rise houses and engage in agricultural activity.
- Umudugudu (new recommended resettlement) – these are the clustered rural settlements created by the government’s rural resettlement programme in 1994 and 2001. These are the recommended habitats for rural households.
- Old resettlement – these are clustered rural settlements dating back to the first government efforts at resettlement in 1978. On average, households in old resettlements have lived there longer than in Umudugudu areas.
- Urban informal/unplanned housing – these are spontaneous, unplanned grouping of households in urban areas. These first started after independence as a result of rural-urban migration and persist to this day.
- Modern planned urban area – these are areas in urban centres that are planned, run, and administered by the government.

5.1.5 Settlement planning

The villagisation programme was officially implemented in the Eastern Province in 2000. During the same period, thousands of households in Musanze District in the Northern Province were advised to move new villages (NISR, 2014). After the success of these new village sites, the government made villagisation compulsory for all rural residents in a law published in 2005 (NISR, 2014). There is no clear reason why the programme started in the Eastern Province.

The Fifth Integrated Household Living Conditions Survey reports a significant increase in the number of households living in Imidugudu (NISR, 2018b). The Eastern province has the highest percentage of population living in Imidugudu, and the Northern Province has had the highest growth rate of Imidugudu between 2014 and 2017. By 2017, these grouped settlements made up 67% of all rural settlements in Rwanda. Almost all of households in Imidugudu are single house dwellings. This has not changed much in the past 5 years. Families living in Imidugudu have, on average, 2.2 people per bedroom, which is the national average. In Rwanda, there is almost no difference in number of people per bedroom between rural and urban areas.

Table *5.1* shows the characteristics of households in the different habitats in Rwanda. Households in Imidugudu are close to the Rwandan average for most of the household characteristics. Households in Imidugudu are larger than households in isolated and clustered rural areas, are made from better building material, are better equipped to deal with rain and a larger percentage of them uses improved sanitation. A larger percentage of them uses electricity as the main source of lighting and are less likely to use rudimentary cooking set ups. They are also closer to roads and clean water sources than households in isolated and clustered rural areas. Households in the upper income quintile and households in urban areas are the least likely to own their dwelling and more likely to rent.

Table 5.1 - Characteristics of the different types of habitats in Rwanda (Note: data obtained from Rwanda's Fifth Integrated Household Living Conditions Survey 2016/17 Utilities and Amenities Thematic Report (NISR, 2018b) and the Main Indicators Report (NISR, 2018a)).

	Isolated rural housing	Unplanned clustered rural housing	**Umudugudu**	Urban unplanned housing	Modern urban planned housing	Rwanda average
Percentage of households in Rwanda (%) (2016/2017)	16.8	6.5	**58.9**	14.2	2.8	
Province						
Kigali City	0.8	0.1	**4.1**	77.3	17.4	15.1
Southern	28.9	8.5	**56.7**	4.8	0.3	23.1
Western	22.1	13	**59.5**	3.1	0	21.2
Northern	21.8	7.1	**68.8**	1.5	0.7	15.6
Eastern	7.6	2.8	**87.4**	2.1	0.1	25
Household and dwelling characteristics						
Households living in a single house dwelling (%)	98.2	92.8	**96.1**	53.8	49.7	88.8
Mean number of people per bedroom	2.3	2.3	**2.2**	2.1	1.9	2.2
Mean floor area of dwelling (m^2)	36.6	37.6	**40.1**	39.1	70.5	40.1
Dwellings with metal sheets as roofing material (%)	39.8	62.5	**67.7**	95.1	97.2	67.3
Dwellings with mud bricks covered with cement as wall material (%)	16.5	23	**27**	57.1	62.9	30.3
Dwellings with cement as floor material (%)	11.1	18	**19.8**	63.5	67.6	25.8
Households with a rainwater catchment system (%)	8.5	11.6	**12.3**	24	51.8	14.5
Access to services						
Households using electricity from the grid as the main source of lighting (%)	5.7	20	**19.5**	73.3	96.1	27.1
Households using charcoal or fuelwood as the primary fuel for cooking (%)	99.3	99	**98.3**	92.4	85.2	97.3
Households using three stone stoves for cooking (%)	73.2	59.6	**56.1**	23.4	5	53.2
Households using efficient cook stoves for cooking (%)	13.3	13.1	**14.8**	8.3	14.7	13.5
Access to water and sanitation services						
Households using improved water sources (% of total)	80.9	87.1	**86.9**	95.2	99	87.4
Mean distance to nearest improved water source (m)	647.8	568.5	**568.2**	260.3	82.5	504.9
Households not using nearest drinking water source (%) *	14.2	13.7	**16.6**	7.3	1.8	14.2
Households using improved sanitation not shared with others (% of total)	64.8	63.2	**73.7**	40.2	56.7	66.2
Occupancy and ownership						
Households that spent more than 20 years in current dwelling (%)	25.2	18.3	**10.4**	5.4	2	12
Households that occupied another dwelling before moving to current dwelling (%) **	67.2	71.3	**74.9**	83.6	90.1	75.1
Dwellings owned by occupying household (%)	86.8	79.7	**84**	39.3	41.8	76.5
Access to infrastructure						
Mean distance an all-weather road (m)	731	427	**258**	130	93	329
WaSH Poverty Index ***						
Water poverty index	0.671	0.684	**0.672**	0.721	0.917	0.697
Sanitation poverty index	0.558	0.587	**0.608**	0.609	0.755	0.608

* Most cited reason for not using the nearest source: Isolated rural housing – Too far; Unplanned clustered rural housing – Does not function; Old resettlement – Too far; Umudugudu – Does not function; Urban unplanned housing – Does not function; Modern urban planned housing – Too expensive.

** Main reason for moving: Isolated rural housing – Get a better house; Unplanned clustered rural housing – Get a better house; Umudugudu – Get a better house; Urban unplanned housing – Renting cost; Modern urban planned housing – Build/buy own house. On average, 27.5% of households across the five habitats reported 'Build/buy own house' as the main reason for changing their accommodation.

*** The WaSH poverty index measures households' access to water, sanitation and hygiene services. The index range is: 0 (risky) to 1 (good).

5.1.6 Electricity access in Rwanda

The government of Rwanda has made significant progress in electrification in the last decade. Electrification increased from 10% in 2010 to 43% in 2018 (World Bank, 2020a). The government plans to achieve universal electrification by 2024 (Ministry of Infrastructure, 2018). In 2016, 23.5% of household had access to grid electricity and 76.5% had no access, of which a small percentage had access to off-grid electricity (Koo *et al.*, 2018a). Of the electrified households, 81.3% have a reliable supply of 8 hours a day of electricity, including 3 hours at night. In urban areas, 77.4% of households have access to the grid (Koo *et al.*, 2018a). In rural areas, only 15.6% of households have access to the grid. Almost half of electrified households have electricity almost all day and every day of the week. But most electrified households experience more than four outages a week (Koo *et al.*, 2018a). A fifth of grid connected households experience voltage fluctuations. In rural areas, two thirds of households use electricity mostly for lighting and phone charging. High connection costs and distance from grid infrastructure are the main barriers to getting an electricity connection for non-electrified households, and a quarter of non-electrified households are willing to pay the full upfront price for a solar device and a third are willing to enter a payment plan (Koo *et al.*, 2018a).

5.1.7 Research proposition

The main purpose of this chapter is to estimate the effect of government resettlement policy on the likelihood of households having access to electricity. The methodology is based on data from an a survey conducted in 2016 on where households live and their access to grid electricity to try and estimate the effect of living in a government planned area.

Proposition: One of the main purposes of the Rwandan government's resettlement programmes is to cluster households in areas where public service provision will be provided and encourage economic activity by proximity. It makes sense that resettlement areas, where population densities are higher than dispersed rural housing, to have better access to public services. This should be especially true for electricity because of the lower costs of provision associated with higher demand. In addition, increased economic activity because of clustering could lead to more households being able to afford an electricity connection. Therefore, the proposition is that households in government planned areas are more likely to have access to electricity than those in unplanned settlements.

5.2 Research methodology

The analysis in this chapter uses survey data from the Rwanda Multi-Tier Framework (MTF) Energy Access Survey (Koo *et al.*, 2018a). The survey is part of Energy Sector Management Assistance Program's (ESMAP) international initiative to collect data on energy access in developing countries at the household level. The MTF approach measures access to energy using a tier system of seven characteristics: capacity, availability, reliability, quality, affordability, formality and health and safety. Each household is then designated a tier rating, ranging from Tier 0 (no access) to Tier 5 (full access).

Despite the added richness of the MTF approach, the analysis in this chapter focuses on whether a household has access to electricity from the grid or not. First a model is developed to estimate the impact of living in different habitats on the likelihood of a household having access to electricity. Then, exploiting the richness of the survey, using willingness to pay data, a second model is estimated to determine if living in an urban area has any impact on households' willingness to pay for an electricity connection.

5.2.1 Data

5.2.1.1 Survey sample

The survey sample consists of 3,295 households from all 5 provinces in Rwanda (all the sampling details of the survey are taken from (Koo *et al.*, 2018b)). The sample of households was chosen using stratified sampling. Selection was conducted in two stages. The first stage: 275 villages were selected from the sampling frame. The second stage: 12 households were chosen from each village. The sampling frame is divided into strata within which households are homogenous.

The number of households in each habitat in the survey sample is shown in Table 5.2. Of the 3,295 households in the survey sample, 1,269 are in habitats classified as Umudugudu, and only 89 and 80 households are sampled from old settlements and modern planned settlements, respectively. Of the remaining households, 764 are in isolated rural areas, 353 are in unplanned clustered rural areas and 714 are in unplanned urban areas.

Figure 5.1 shows raincloud plots of income distribution of households in the different habitats in the survey sample, with the log of monthly household income on the y-axis. The boxplots show the distribution of monthly household income in each habitat. Households in planned urban areas have the highest mean monthly household income, followed by households in unplanned urban areas and households in Umudugudu. Understandably, households in isolated rural areas have the lowest mean monthly household income.

Table 5.2 - Household distribution across habitats in the survey sample.

Habitat	**Sample size**
Isolated rural housing	764
Unplanned clustered rural housing	353
Umudugudu (new recommended rural settlement)	1,269
Old resettlement	89
Urban informal/unplanned housing area	714
Modern planned urban area	80
Total	3,295

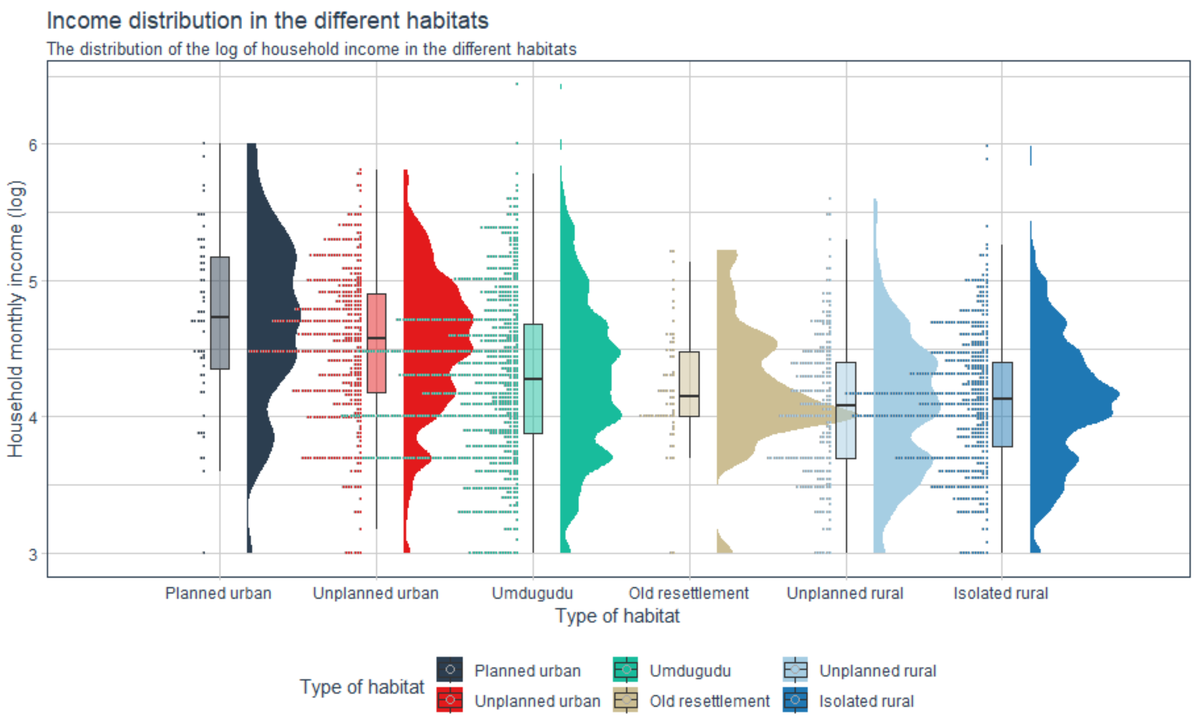

Figure 5.1 - Raincloud plot of income distribution of households in each habitat.

Figure *5.2* shows the distribution of average monthly income, average years of education[19], years of living in the community and number of household members for the whole population. Most households have 4 to 6 years of schooling and most households between 3 to 6 members. Most households tend to live for 10 years or less in a specific community.

Using the survey weights to reflect the distribution of households across habitats in Rwanda, the proportion of households in each habitat and the proportion of households with access to electricity is shown in Figure *5.3*. Most households in Rwanda are in isolated rural areas and government planned settlements (Umudugudu). These households, along with households in unplanned rural areas and old resettlements are the least electrified. Households in urban areas, in both informal and modern settlements, have the highest level of access to electricity.

[19] See Section 5.2.2.3 for how the income and education variables were calculated from the survey data.

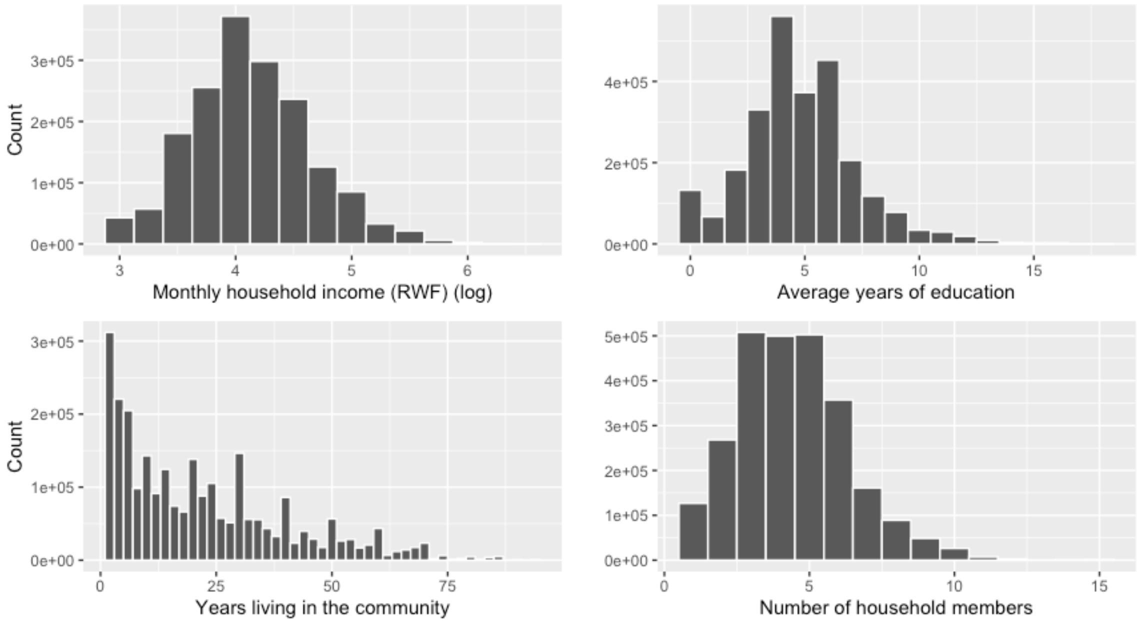

Figure 5.2 - Distributions of income, years of education, years living in the community and number of household members in the entire population.

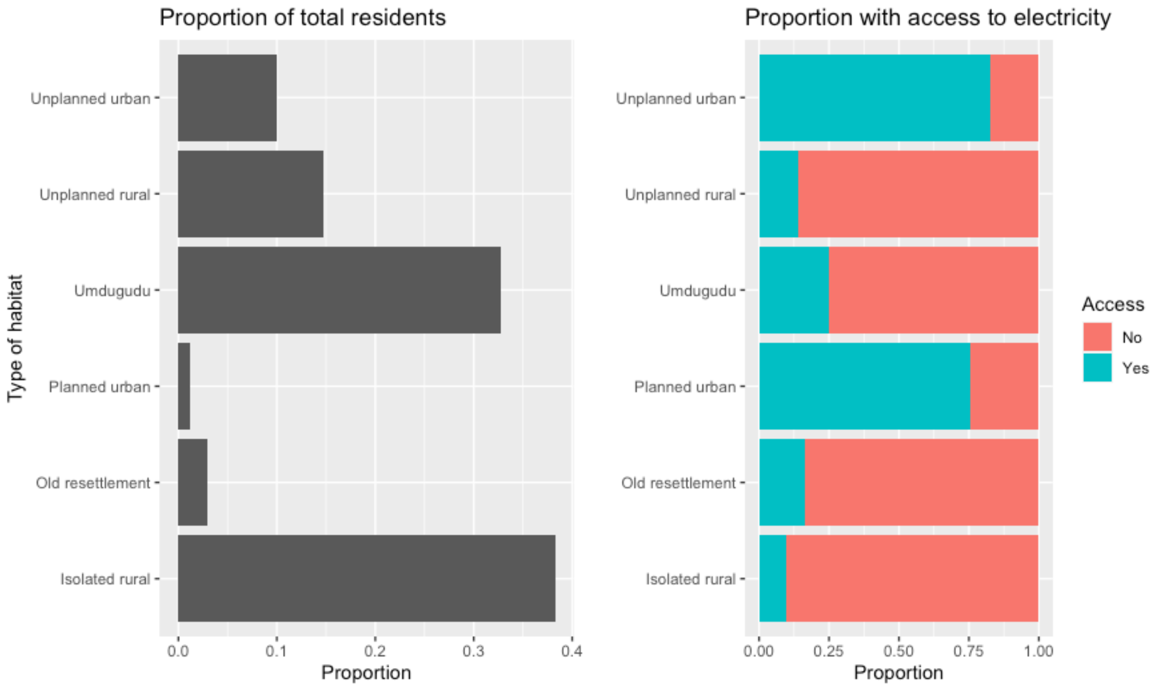

Figure 5.3 - Proportion of households in each habitat and the respective electrification status.

The survey includes data on income and level of education of each household member. The average monthly income (in Rwandan Francs, RWF)[20] and the average years of education of households in the different habitats are shown in Figure *5.4*. Households in urban areas have higher incomes and higher levels of education than households in rural areas. Across rural settlements, households in the government planned villages have higher average incomes and marginally higher levels of education than households in other rural settlements.

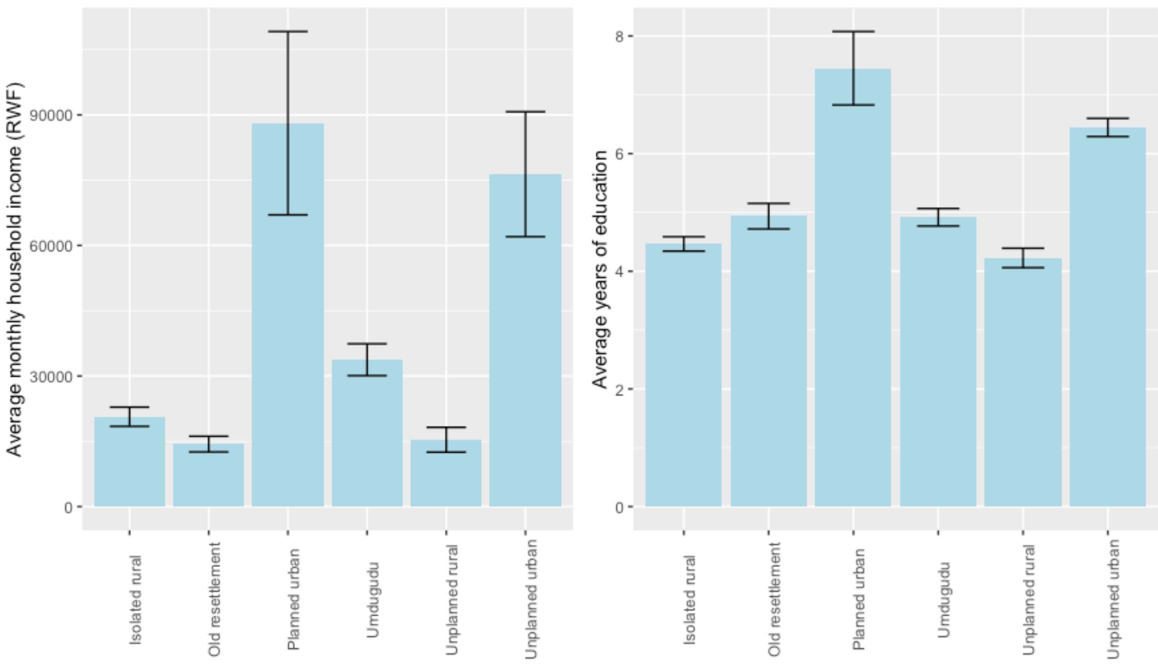

Figure 5.4 - Average monthly income and average years of education across the different habitats (with error bars).

Using the sample weights to reflect the distribution within the population, Figure *5.5* shows the Kernel density plots of average monthly income of households in the different habitats based on their electrification status. Except for households in old resettlements, households with access to electricity tend to have higher incomes. This is particularly more pronounced in planned urban areas. This is

[20] In 2016, US$ 1 = RWF 780.

intuitive because households without access to electricity in modern planned areas are less likely to be able to afford housing.

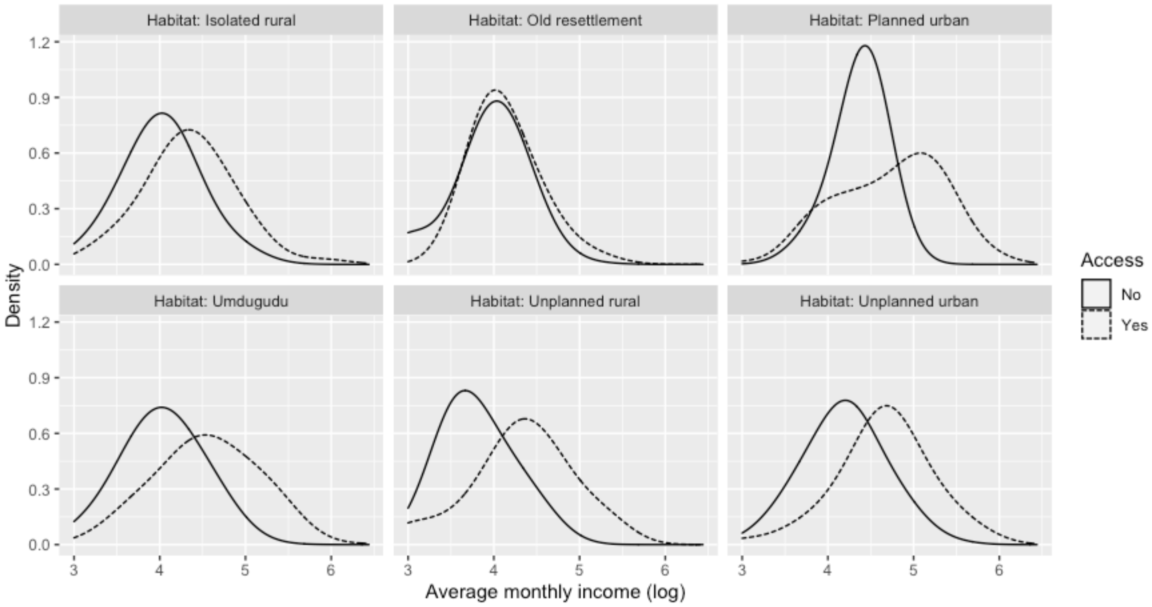

Figure 5.5 - Kernel density plots of monthly income for households by access to electricity status of households.

Figure *5.6* shows a plot of average monthly income against average years of education for households with and without access to electricity. The trend line showing the relationship between education and income is steeper for households with access to electricity. This is potentially evidence of the positive impact of electricity on the income returns of education, where the same number of years of education corresponds to a higher income for households with access to electricity.

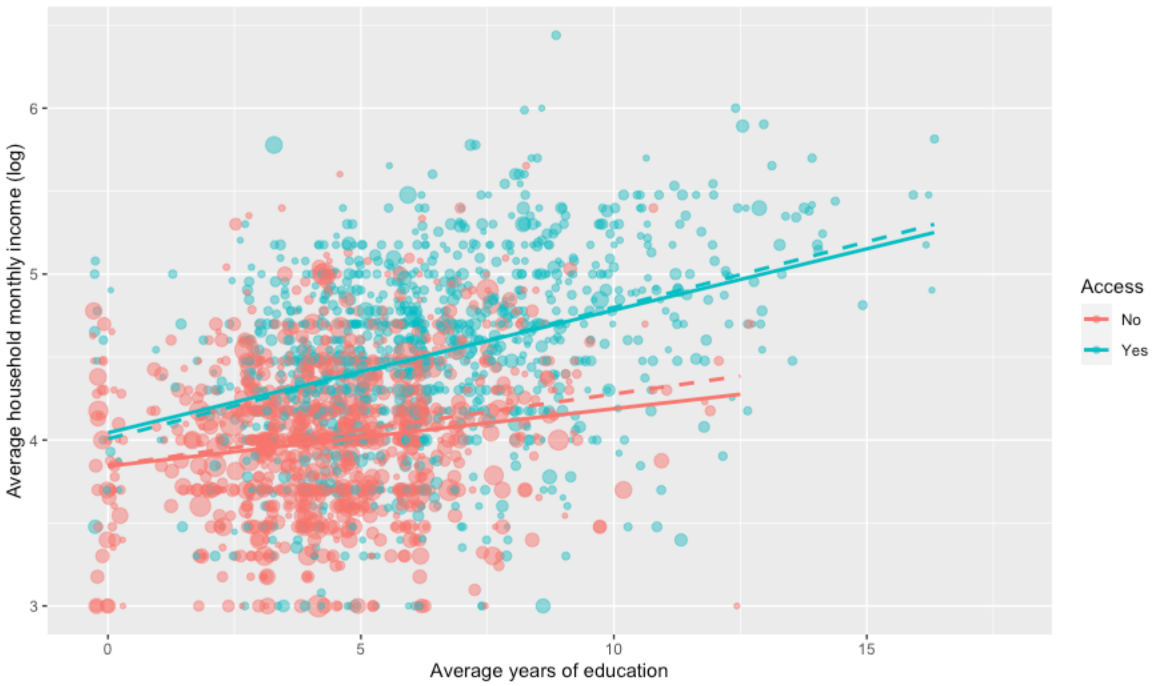

Figure 5.6 - Average monthly income vs average years of education by access to electricity status of households (dashed trend lines show trends for the sample not including sample weights; size of the bubble is the sample weight of each observation; graph plotted with jitter).

On average, households with access to electricity tend to live nearer to towns and are in sectors with higher population densities. Across habitats, households in government planned villages live nearer to towns and are located in sectors with higher population densities than households in other rural settlements (Table *5.3*).

Table 5.3 - Average distance from nearest town and average population density of sector for households with and without access to electricity and for households in the different types of habitats.

	Distance from nearest town (km)	Population density of Sector (people per sq km)
Electricity access		
No	24.8	527
Yes	10.4	1,625
Type of habitat		
Isolated rural housing	26.5	525
Unplanned clustered rural housing	22.6	544
Umudugudu (new recommended rural settlement)	18.8	789
Old resettlement	21.5	667
Urban informal/unplanned housing area	7.3	2,197
Modern planned urban area	4.9	1,796

The survey data shows there are clear disparities in household characteristics across habitats. Most households in Rwanda are in rural or government planned habitats. Households in urban areas tend to have higher incomes and higher levels of education than households in rural areas. Households in urban areas also have higher rates of electricity access. Across the different types of habitats, households in Umudugudu have higher incomes, higher levels of education and higher rates of access to electricity than households in other rural settlements. Households in Umudugudu also tend to live nearer to towns and are in sectors with higher population densities.

The next section two sub-sections, Sections 5.2.2 and 5.2.3, uses this exploratory analysis to specify an estimation strategy to determine the different likelihoods in access to grid electricity for households across the different habitats.

5.2.2 Variables

5.2.2.1 Dependent variable

This analysis uses connection to the national grid as the main dependent variable. Primarily, because this is the most direct way through which government energy policy acts with regards to electricity. Using electricity consumption as the dependent variable would indicate post-connection supply allocation, as opposed to provision of electricity. Connections to mini-grids, which could perhaps be government funded or facilitated, are not considered because only 8 households in the whole sample are connected to mini-grids.

The main dependent variable, therefore, is whether a household has access to grid electricity. Survey question C2 asks, “Is the household connected to the national grid?”. The respondent (the head of the household) can answer “Yes” or “No.” There is no reason to doubt the accuracy of the recorded response for two reasons: whether the household is connected to the grid or not is visually verifiable by the enumerator, and the stratification strategy depends on the accuracy of the response to this question. Of the 3,295 households in the survey, 1,632 are connected to grid electricity and 1,663 are not. The 50-50 split between electrified and non-electrified households is dictated by the stratification strategy (see Appendix C). When considering the stratification strategy and factoring in the primary sampling units, sampling weights and the strata variable, the split becomes more representative of the larger population: 76.4% not electrified and 23.6% electrified.

Ideally, to make full use of the MTF's approach to measuring electricity access, the main dependent variable should be the level of a household's access to electricity using the MTF's tier system. However, because of the tier distribution of households in Rwanda (73.2% are Tier 0 and 26.8% are the Tiers 1 to 5) and the lack of significant variation across households, it makes more sense to use the binary variable of access to grid electricity. Using the household tier instead of access to grid electricity would ultimately give similar results.

The analysis on the likelihood of access to electricity across habitats does not consider hours of electricity, or reliability of electricity. Although reliability is important, it would fit into the analysis as a dependent variable instead of access, but because hours of electricity implies that an electricity connection exists, then the analysis would have to look at how other household and community characteristics affect hours of electricity given that the household has a connection to the grid. Having said that, as we've established in Chapter 4, it is possible that policy impacts hours of electricity in the same way that it impacts electricity access.

This analysis does not consider household's choice of main source of electricity. Of the 1,632 households that are connected to the grid, 1,574 say they use the grid as the main source of electricity. The analysis, therefore, assumes that every household that has a grid connection uses it for their electricity needs.

5.2.2.2 Explanatory variables

The main explanatory variable is type of habitat. The households sampled in the MTF survey are distributed across the different types of habitats in Rwanda. The different habitats are shown in Table 5.2. The main objective of the habitat variables is to measure the effect of a household being in a government planned Umudugudu on the likelihood of that household having a grid connection. If the effect is positive, then the policy of creating planned rural areas, while controlling for the government's preference for certain areas over others (or the financial and practical feasibility), has a positive impact on electrification through clustering and centralising demand.

Coding the habitat variable ranks habitats from most traditional, rural-like to most modern, urban-like, using the government's definition of each type of habitat (Section 5.1.4). Isolated rural housing is used as the reference category. A dummy variable is created for each of the other five habitats. The analysis makes several assumptions about the interpretation of the coefficients of the habitat dummies: the coefficient of the unplanned clustered rural housing dummy is interpreted as the effect of clustering; the coefficient of the Umudugudu dummy gives the effect of government planned clustering; the coefficient of the old resettlement dummy will give the long-term effects of government planned clustering; the coefficient of the urban unplanned dummy will give the effect of living in an urban area; and the coefficient of the modern planned urban dummy will give the effect of planned modern urban living.

An urbanisation dummy indicating whether a community is in an urban or rural area is used to gauge the impact of being in an urban area on the likelihood of access to electricity.

5.2.2.3 Control variables

To isolate the effect of the government's settlements policy, the analysis controls for several drivers of electrification. There are several factors that affect households' ability to access and use electricity: income, proximity to markets and urban centres and a household's demographic and socio-economic characteristics. The model controls for three types of variables: household characteristics, community characteristics and regional demographic characteristics. The model also controls for centralisation by including a dummy for households living in Kigali province, where the capital city is located.

The variables of household characteristics include monthly income, average years of education, number of households sharing the dwelling, the number of household members with a bank account and how long households have lived in the community. Monthly income controls for household's ability to afford a grid connection. Average years of education controls for household's understanding of, and ability to see the benefit in, access to electricity and access to other public services. Since a connection to the grid requires a significant financial commitment, the more households see the benefit in having access to electricity the more likely they are to commit financially. And households with higher levels of education are more likely to live in an area where there is access to education. The number of households sharing the dwelling controls for the pooling effect of incomes from different households. The variable measuring the number of household members with a bank account controls for households' ability to pay for a grid connection outright or using instalments. The number of years a household has lived in a community account for how settled households feel, which affects investment decisions.

The community characteristics variables include distance to the nearest town, whether the community has a grid connection and number of years the community has had a grid connection. Distance to the nearest town accounts for the government's ability to connect communities to the grid. There is little variation in grid connection fees across communities and there is no discernible relationship between distance from nearest town and grid connection fee. Therefore, this variable also accounts for the government's grid expansion plan. The variable signifying whether a community has a grid connection, accounts for the availability of grid electricity to households that are able and willing to pay for a connection. The variable measuring the number of years a community has had a grid connection accounts for the length of time the opportunity to get a grid connection has been available to households in the community.

The model also controls for regional and demographic data. The population density of each sector is used to account for the government's targeting of areas that are more populous than others and would thus have larger aggregate demand for electricity. This is a popular strategy to increase the cost efficiency of expanding the grid. Finally, a dummy for Kigali province is used to control for households in the central province to control for the effect of centralisation on a household's likelihood of having access to the grid. Table 5.4 below lists the variables used in the analysis.

Table 5.4 - Variables used in the model estimation.

Variable	Definition	Survey question
Dependent variable		
Access to grid electricity	Whether the household is connected to the national grid	C2
Explanatory variables		
Habitat	Type of habitat the household is in	B5
Locality	Whether the community is in an urban or rural area	Locality
Control variables		
Household characteristics (Household questionnaire)		
Average monthly income (log)	The average monthly income of the income generating activities of all working members of the household	A20*
Average years of education	The average number of years of education all household members	A9*
Number of households sharing the dwelling	Number of families sharing the dwelling	B6
Household members with bank accounts	Whether there are members of the household with bank accounts at a formal financial institution	B22
Number of years in the community	How many years a household has lived in the community	B4
Community characteristics (Community questionnaire)		
Distance to the nearest city	Distance in kilometres from the community to the nearest city	D3
Community has a grid connection	Whether the community the household is in has a grid connection	Created**
Years with a grid connection	Number of years the community has had a grid connection	L7
Sector characteristics		
Population density (by sector)	Population density of each sector in each province	Rwanda 2012 Population Census
Centralisation (Household questionnaire)		
City of Kigali	Whether the household, located in a rural or urban area or in any habitat, is in Kigali province	Province

* See Data Manipulation in Appendix C to see how this variable was created using the survey data.

** This variable was created in the process of creating the Strata variable for the analysis. See Creating the Strata variable sub-section in Appendix C to see how this variable was created.

5.2.2.4 Supplementary analysis on willingness to pay for electricity

Improving the electrification status of households in developing countries is an expensive endeavour. For households with no access to electricity, one major determinant of whether they get access or not is their willingness to pay (WTP) for an electricity connection. There is some evidence that the benefits to households from having access to grid electricity is low in relation to the large cost of expanding the grid (Sievert and Steinbuks, 2020; Deutschmann, Postepska and Sarr, 2021). Furthermore, another major finding in the literature is that households' willingness to invest in electricity is driven by their income and access to credit (Gertler *et al.*, 2016). Having said that, the aim of the WTP analysis in this chapter is to provide more evidence on the impact of habitat on likelihood of electricity access.

To do that, data from the survey is used to determine the impact of being in an urban area on households' WTP for electricity. The analysis uses two dependent variables: households' WTP a one-time payment and payment in instalments. The main explanatory variable is an urban variable that takes a value of 1 if a household is in an urban area, and 0 otherwise. The control variables are informed by the literature and include household characteristics, access to finance and electricity attributes at the community level. Household characteristics include income, education, and sex and age of the head of the household. Access to finance variables include whether a member of the household has a bank account, whether households use mobile money and if households have access to credit. These variables are proxies for how credit constrained households are, which affects investment decisions. Whether a household owns the home they live in is included to account for asset ownership. Finally, using the MTF's framework, three criteria of electricity are included at the community level: reliability, availability, and quality. These are calculated at the community level by taking the average value for the households that do have access to electricity.

5.2.3 Empirical estimation

5.2.3.1 Access to electricity

The first objective of the estimation exercise is to determine the likelihood of a household having access to electricity depending on whether the household is in a government planned settlement. The first model estimates the effect of living in a specific habitat on the likelihood of having access to electricity. The first model is estimated by a logistic regression for household i in community v in sector s and habitat j:

$$logit(y_{i,v,s,j}) = \beta_0 + \sum_{j=1}^{5} \beta_{1j} H_{ij} + \boldsymbol{\beta X}_i + \boldsymbol{\beta X}_v + \boldsymbol{\beta X}_s + \beta_n K_i + \gamma_s \tag{5.1}$$

where y_i is an electricity access binary variable, which takes a value of 1 if household i has access to electricity, and 0 otherwise, and is a function of the habitat where the household is in, defined by the binary indicator H_{ij}, which takes the value 1 if household i is in habitat j.[21] Household, community, demographic, and regional characteristics, and sector fixed effects, are sequentially added. Sector fixed effects are included because that's the lowest administrative level where policy is implemented. $\boldsymbol{X}_i$ is a vector of household characteristics, $\boldsymbol{X}_v$ is a vector of community characteristics, $\boldsymbol{X}_s$ is a vector of sector demographic characteristics, K_i is a Kigali dummy, which takes a value of 1 if household i is in Kigali province, and 0 otherwise, and γ_s is a vector of sector fixed effects. The coefficients of interest, β_{1j}, where $j \in (1,5)$, represent the likelihood of a household in habitat j having access to electricity compared to the reference habitat category, isolated rural.[22]

A second model is estimated to determine the difference in likelihood of access to electricity between households in urban and rural areas

$$logit(y_{i,v,s}) = \beta_0 + \beta_1 U_i + \boldsymbol{\beta X}_i + \boldsymbol{\beta X}_v + \boldsymbol{\beta X}_s + \beta_n K_i + \gamma_s \tag{5.2}$$

where U_i takes a value of 1 if a household i is in an urban area, and 0 otherwise.

[21] Where $logit(y_i) = log\left(\frac{p(y_i)}{1-p(y_i)}\right)$.

[22] More specifically, the value of the coefficients of interest are log-odds. For ease of interpretation, odds ratios are reported in the results tables.

Finally, a model is estimated to determine intersectionality between urbanicity and centralisation. In this estimation, an interaction term is introduced between the urban variable and Kigali variable:

$$logit(y_{i,v,s}) = \beta_0 + \beta_1 U_i + \beta_2 K_i + \beta_3 (U_i \times K_i) + \boldsymbol{\beta X}_i + \boldsymbol{\beta X}_v + \boldsymbol{\beta X}_s + \gamma_s \quad (5.3)$$

where β_3 is the coefficient of the interaction term between the urban variable and Kigali variable. Like the previous estimations, household, community, and demographic characteristics, and sector fixed effects, are sequentially added. For all the estimated models, an F-test is conducted to check if the models with the interaction terms are better than identical models without interaction terms.

Table 5.5 - Summary statistics of variables used in the first estimation.

Descriptive statistics

Statistic	N	Mean	St. Dev.	Min	Pctl(25)	Pctl(75)	Max
Access to grid electricity	3,295	0.5	0.5	0	0	1	1
Monthly income (log)	2,198	4.3	0.6	3.0	3.9	4.7	6.4
Household education	3,295	5.5	2.8	0.0	3.8	6.9	18.0
Number of households in the dwelling	3,295	0.3	0.8	0	0	0	9
Household members with bank account	3,295	0.5	0.5	0	0	1	1
Number of years in the community	3,295	18.1	16.2	1	5	26	95
Distance from nearest city	2,360	16.1	16.4	1.0	3.0	25.0	99.0
Community has a grid connection	3,295	0.7	0.5	0	0	1	1
Number of years with grid connection	2,360	12.1	13.5	0.0	2.0	20.0	66.0
Population density of sector	3,295	2.8	0.4	1.7	2.6	2.9	4.0

Table 5.6 - Household and community characteristics for households with and without access to electricity.

	Access to electricity		No access to electricity	
Statistic	Mean	Median	Mean	Median
Household characteristics				
Monthly income (log)	4.5	4.5	4.0	4.0
Household education (years)	6.5	6.0	4.5	4.5
Household members with bank account	0.7	1	0.3	0
Number of years in the community (years)	15.0	10	21.1	16
Distance from nearest city (km)	11.9	6.0	20.2	15.0
Community characteristics				
Community has a grid connection	0.9	1	0.4	0
Number of years with grid connection (years)	15.8	12.0	8.6	3.0
Sector characteristics				
Population density of sector (log)	3.0	2.8	2.7	2.6

The summary statistics of the variables used in the estimation are presented in Table *5.5*. And Table *5.6* presents the mean and median of each variable for households with and without access to electricity.

5.2.3.2 Willingness to pay for electricity

The most common method for extracting the values people are willing to pay for goods or services is contingent valuation. There are different ways of doing this, but the methods can be broadly categorised as open-ended or as bidding games. In the former, respondents are asked how much they are willing to pay for a good or service. In the latter, a respondent’s willingness-to-pay is elicited through an auction-like process. The most popular formats of auction-like contingent valuation are single-bounded dichotomous choice (SBDC) and double-bounded dichotomous choice (DBDC) (Aizaki, Nakatani and Sato, 2014). In SBDC, first proposed by Bishop and Heberlein (1979), respondents are asked if they are willing to pay a specific amount for a good or service, and they are required to reply with either “yes” or “no”. The response produces a binary variable. DBDC is an improvement on the efficiency of SBDC, proposed by Hanemann (1985), where respondents are asked a follow-up question depending on their response to the first SBDC question: respondents are asked if they’d be willing to pay a higher price than they were initially asked to pay if they responded “yes” and a lower price than they were initially asked to pay if they responded “no”. The follow-up question provides more information about the exact amount a respondent is willing to pay for a good or service.

In the MTF survey, despite there being two consecutive willingness-to-pay questions, they are not structured as DBDC-style questions. The first asks the respondent if they are willing to pay 58,000 RWF for an electricity connection, if they answer “no” then they are asked if they are willing to pay 15,000 RWF upfront and the rest in instalments. For this reason, both questions are treated as separate SBDC-style questions and the binary response to each question is used as a dependent variable to understand the factors that influence willingness-to-pay. The binary response to the first question is interpreted as whether a respondent is willing to pay the full amount for an electricity connection or not.

The binary response to the second question is interpreted as whether a respondent is willing to pay for an electricity connection in instalments given that they're not willing to pay the full cost upfront.

The factors that determine respondents' willingness-to-pay for electricity are estimated using a logit model. Two models are estimated, one for each of the two questions described above, using a subset of the data of households without access to electricity. Both models estimate the logistic regression

$$logit(wtp_{i,v,s}) = \beta_0 + \boldsymbol{\beta X}_i + \boldsymbol{\beta X}_v + \beta_n U_i + \gamma_s \tag{5.4}$$

where $wtp_{i,v,s}$ is whether household i in community v in sector s is willing to pay for an electricity connection. Both models control for a set of households and community variables: households' access to finance, and the quality, reliability, and availability of electricity at the community level. For the first model, the dependent variable is a dummy for whether a household is willing to make a one-time payment for an electricity connection. In the second model, the dependent variable is a dummy for whether a household is willing to make a small up-front payment and pay the rest of the fees for an electricity connection in instalments. Both models are estimated twice, once with and once without sector fixed effects. An urbanisation variable is added to the right hand of Equation (5.4) to control for whether households are in rural or urban areas. The variable takes a value of 1 if household i is in an urban area, and 0 otherwise. For all the estimations, McFadden's pseudo R-squared is reported.

The summary statistics of the variables used in the estimation are presented in Table *5.7*.

Table 5.7 - Summary statistics of variables used in the second estimation.

Descriptive statistics

Statistic	N	Mean	St. Dev.	Min	Pctl(25)	Pctl(75)	Max
Willingness to pay for electricity (one-time payment)	1,662	0.1	0.4	0.0	0.0	0.0	1.0
Willingness to pay for electricity (instalments)	1,419	0.4	0.5	0.0	0.0	1.0	1.0
Household monthly income (log)	1,069	4.0	0.5	3.0	3.7	4.3	5.7
Household education	1,663	4.5	3.5	0	0	6	17
Sex of head of household	1,658	0.7	0.5	0.0	0.0	1.0	1.0
Age of head of household	1,663	46.8	15.5	26	34	57	98
Household members with bank account	1,663	0.3	0.5	0	0	1	1
Access to credit/loans	1,663	0.4	0.5	0	0	1	1
Uses mobile money	1,663	0.3	0.4	0	0	1	1
House ownership	1,663	0.8	0.4	0	1	1	1
Reliability of electricity	928	0.9	0.3	0.0	1.0	1.0	1.0
Quality of electricity	1,083	0.8	0.4	0.0	1.0	1.0	1.0
Availability of electricity	1,663	0.3	0.4	0	0	1	1

5.3 Results

5.3.1 Access to electricity across habitats and localities

Table *5.8* presents results from estimating Equation (5.1). The outcome variable is whether a household has access to electricity. Columns (1) through (6) gradually add household, community, and sector characteristics. The intercept in Column (1) shows that the odds of a household in an isolated rural area (the reference category) having access to electricity are 0.105, and the odds of having access to electricity vary significantly across habitats. Column (2) presents the results of estimating the base model while controlling for whether a household is in an urban or rural area. More importantly, the results suggest that, specifically for urban settlements, there's a notable decrease in the likelihood of having access to electricity after controlling for household, community, and sector fixed effects. Column (7) shows the results of the estimation controlling for sector fixed effects. On average, the odds of a household in an Umudugudu having access to electricity is 122% higher than the odds for a household in an isolated rural area. For unplanned rural and unplanned urban, the odds are higher by 107% and 114%, respectively.

Table 5.8 - Regression results of the estimation of the first model: effect of type of habitat on access to electricity.

	Dependent variable:						
	Access to electricity						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Type of habitat (reference category: Isolated rural)							
Umudugudu	3.127***	2.071***	1.457	2.636***	2.495***	2.492***	2.215**
	(0.241)	(0.247)	(0.246)	(0.241)	(0.256)	(0.258)	(0.360)
Unplanned rural	1.574	1.604	2.252***	2.397***	2.183**	2.178**	2.068*
	(0.288)	(0.297)	(0.277)	(0.326)	(0.322)	(0.323)	(0.386)
Unplanned urban	45.691***	8.289***	5.341***	3.956***	2.920***	2.325**	2.144*
	(0.322)	(0.332)	(0.333)	(0.356)	(0.371)	(0.345)	(0.445)
Old resettlement	1.844	1.760	2.873	2.414	2.127	2.009	3.049**
	(0.522)	(0.575)	(0.646)	(0.574)	(0.535)	(0.522)	(0.523)
Modern urban	29.144***	10.482***	4.809*	2.390	1.708	1.610	2.442
	(0.779)	(0.601)	(0.920)	(1.012)	(1.049)	(1.023)	(1.061)
Intercept	0.105***	0.088***	0.0002***	0.0001***	0.00000***	0.00000***	0.0001***
	(0.206)	(0.223)	(0.833)	(1.244)	(1.591)	(1.604)	(2.172)
Sector fixed effects	No	No	No	No	No	No	Yes
Locality dummy	No	Yes	Yes	Yes	Yes	Yes	Yes
Household characteristics	No	No	Yes	Yes	Yes	Yes	Yes
Community characteristics	No	No	No	Yes	Yes	Yes	Yes
Population density	No	No	No	No	Yes	Yes	No
Kigali dummy	No	No	No	No	No	Yes	No
McFadden's pseudo R-squared	0.21	0.3	0.39	0.48	0.49	0.49	0.59
Observations	3,269	3,269	2,180	1,572	1,572	1,572	1,572

Note: *p<0.1; **p<0.05; ***p<0.01
Coefficients reported are odds ratios instead of log odds (standard errors and p-values are unchanged).

Table 5.9 - Regression results of the estimation of the second model: effect of locality on electricity access.

	Dependent variable:			
	Access to electricity			
	(1)	(2)	(3)	(4)
Locality (reference category: Rural)				
Urban	22.751***	2.736***	2.249***	1.185
	(0.245)	(0.262)	(0.266)	(0.652)
Intercept	0.138***	0.00000***	0.00000***	0.0001***
	(0.115)	(1.684)	(1.683)	(2.310)
Sector fixed effects	No	No	No	Yes
Household characteristics	No	Yes	Yes	Yes
Community characteristics	No	Yes	Yes	Yes
Population density	No	Yes	Yes	No
Kigali dummy	No	No	Yes	No
McFadden's pseudo R-squared	0.26	0.47	0.48	0.59
Observations	3,295	1,588	1,588	1,588

Note: *p<0.1; **p<0.05; ***p<0.01
Coefficients reported are odds ratios instead of log odds (standard errors and p-values are unchanged).

The second set of results compare the likelihood of access to electricity between households in rural and urban areas for the same outcome variable. Table *5.9* presents the results from estimating Equation (5.2). Columns (1) to (4) progressively add household, community, and sector characteristics. The intercept in Column (1) shows that the odds of a household in a rural area having access to electricity is 0.138 (this, unsurprisingly, is higher than the intercepts in Column (1) in Table *5.8*), and the odds ratio of a household in an urban area having access to electricity, β_1, the coefficient of interest, is 22.8.[23] The value of the coefficient decreases as household, community and sector characteristics are added. There's a significant difference in the value of β_1 between Column (2) and (3) after adding the Kigali dummy to the model. Ultimately, Column (4) shows that, after introducing sector fixed effects while controlling for household and community characteristics, the effect of being in an urban area relative to being in a rural area on the likelihood of having access to electricity is not statistically significant.

5.3.2 Interactions: Urban and Kigali

The third set of results examines the intersectionality between urbanisation and the central province, Kigali. This is achieved by introducing an interaction term of the urban and Kigali variables. The urban variable takes a value of 1 if a household is in a habitat in an urban area, and 0 otherwise, and the Kigali variable takes a value of 1 if a household is in a habitat in Kigali province, and 0 otherwise.

Table *5.10* presents the results from estimating Equation (5.3). The outcome variable is whether a household has access to electricity. Column (1) presents the estimates of the model without any controls. Columns (2) and (3) present the model estimates with household, community, and demographic characteristics, and sector fixed effects. The coefficients reported are log-odds. The Kigali and

[23] The odds ratio of a household in an urban area having access to electricity is the odds of a household in an urban area having access to electricity divided by the odds of a household in a rural area having access to electricity:

$$OR = \frac{Households\ in\ urban\ areas\ with\ electricity / Households\ in\ urban\ areas\ without\ electricity}{Households\ in\ rural\ areas\ with\ electricity / Households\ in\ rural\ areas\ without\ electricity}.$$

urban variables are not statistically significant in Column (2) and (3), respectively. However, the F-test statistic shows that the interaction is significant.

The intercept is the log-odds of having access to electricity for a household in a rural area not in Kigali province (this corresponds to an odds ratio of 0.133). The coefficient for the Kigali variable (β_1) only captures the effect of being in Kigali for households in rural areas. Similarly, the coefficient for the Locality variable (β_2) only captures the effect of being in an urban area for households not in Kigali. The coefficient for the interaction term (β_3) is the difference between the log-odds comparing households in urban versus rural areas in Kigali province and the log-odds comparing households in urban versus rural areas not in Kigali province, or, similarly, it is the difference between the log-odds comparing households in Kigali province versus households not in Kigali province in urban areas and the log-odds comparing households in Kigali province versus households in not in Kigali province in rural areas.

Due to the inclusion of the interaction effect, the meaningful odds ratios need to be derived from the log-odds. For households in rural areas, the odds ratio of having access to electricity for households in Kigali versus those that are not in Kigali is $exp(\beta_1)$. For households in urban areas, the odds ratio for being in Kigali versus not being in Kigali is $exp(\beta_1 + \beta_3)$. For households not in Kigali, the odds ratio of having access to electricity for households in urban areas versus households that are not is $exp(\beta_2)$. For households in Kigali, the odds ratio for having access to electricity in an urban area versus being in a rural area is $exp(\beta_2 + \beta_3)$. For a comparison of households in urban areas in Kigali versus households in rural areas not in Kigali, the odds ratio is $exp(\beta_1 + \beta_2 + \beta_3)$.

Table *5.11* presents the meaningful odds ratios for the three models estimating the interaction between the urban and Kigali variables. The coefficients for the interaction variable and the Locality variable are significant in all three models. The coefficient of the Kigali variable is not statistically significant in Column (2) of Table *5.10*. This suggests that, when controlling for household, community and demographic characteristic, for households in rural areas, being in Kigali versus other provinces has no impact on their likelihood of having access to electricity.

Table 5.10 - Regression results of the estimation of the third model: intersectionality between urbanisation and Kigali.

	Dependent variable:		
	Access to electricity		
	(1)	(2)	(3)
Kigali (reference category: Not Kigali)	0.872	-0.053	-2.701*
	(0.532)	(0.654)	(1.351)
Locality (reference category: Rural)	2.302***	0.535*	-0.240
	(0.278)	(0.281)	(0.701)
Kigali x Locality	1.458**	1.599**	3.197**
	(0.665)	(0.804)	(1.264)
Constant	-2.014***	-12.537***	-9.701***
	(0.119)	(1.708)	(2.380)
Sector fixed effects	No	No	Yes
Household characteristics	No	Yes	Yes
Community characteristics	No	Yes	Yes
Population density	No	Yes	No
McFadden's pseudo R-squared	0.3	0.48	0.59
Interaction F-test	0.022	0.042	0.009
Observations	3,295	1,588	1,588

Note: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$
Coefficients reported are log-odds: this is for ease of interpretation as both the Kigali and urban variables can no longer be interpreted on their own because of the presence of the interaction tern. The Interaction F-test statistic presents the p-value of an F-test conducted to determine whether the models with interaction terms are significantly better than identical models without an interaction term.

Table 5.11 - Odds ratios for the interaction between the urban and Kigali variables.

		Odds ratios		
	Coefficients	Model (1)	Model (2)	Model (3)
$\frac{\text{Odds for (Locality} = 0 \text{ and Kigali} = 1)}{\text{Odds for (Locality} = 0 \text{ and Kigali} = 0)}$	$\exp(\beta_1)$	2.39	0.95	0.07
$\frac{\text{Odds for (Locality} = 1 \text{ and Kigali} = 1)}{\text{Odds for (Locality} = 1 \text{ and Kigali} = 0)}$	$\exp(\beta_1 + \beta_3)$	10.28	4.69	1.64
$\frac{\text{Odds for (Locality} = 1 \text{ and Kigali} = 0)}{\text{Odds for (Locality} = 0 \text{ and Kigali} = 0)}$	$\exp(\beta_2)$	9.99	1.71	0.79
$\frac{\text{Odds for (Locality} = 1 \text{ and Kigali} = 1)}{\text{Odds for (Locality} = 0 \text{ and Kigali} = 1)}$	$\exp(\beta_2 + \beta_3)$	42.95	8.45	19.24
$\frac{\text{Odds for (Locality} = 1 \text{ and Kigali} = 1)}{\text{Odds for (Locality} = 0 \text{ and Kigali} = 0)}$	$\exp(\beta_1 + \beta_2 + \beta_3)$	102.72	8.01	1.29

In Column (3), the coefficient of the Locality variable is not statistically significant, which suggests that, controlling for sector fixed effects, for households not in Kigali province, being in an urban area does increase the likelihood of having access to electricity versus being in a rural area. Unsurprisingly, the largest difference in odds of access to electricity is between households in urban areas in Kigali and households in rural areas not in Kigali. In the base model, for households in urban areas in Kigali the odds of having access to electricity are 100 times more than households in rural areas not in Kigali. This difference in odds, however, significantly decreases as control variables are added.

5.3.3 Willingness to pay for electricity

Table *5.12* presents the results from estimating Equation (5.4). The outcome variable is willingness to pay (WTP) for electricity. Columns (1) and (2) show the estimates of the effects of the explanatory variables on households' willingness to make a one-time payment. Columns (3) and (4) show the estimates of the effects of the explanatory variables on households' willingness to pay for electricity in instalments. Columns (2) and (4) include sector fixed effects.

For the models with sector fixed effects (Columns (2) and (4)), the monthly income variable is positive and significant, as expected, indicating that households with higher incomes are more likely to be willing to pay for electricity. Education of household members and the sex of the head of the household both have a positive effect on WTP but are not statistically significant. The age of the head of the household has a negative effect on WTP for electricity in instalment (and no statistically significant effect on WTP a one-time payment), where a one year increase in age reduces the odds of a household's WTP for electricity by 4%. Access to credit has a positive impact on WTP using instalments, but no effect on one-time payment. Households that use mobile money have 850% and 954% higher odds of paying for electricity using a one-time payment and instalments, respectively. Owning a housing has no effect on the outcome variable. Quality of electricity has a positive and significant effect on WTP using instalments, while availability of electricity has a positive and significant effect on WTP with a one-time payment.

Households in urban areas are less likely to be willing to pay a one-time payment for an electricity connection than households in rural areas. The opposite is true for instalments, where households are much more likely to be willing to pay using an instalments plan. However, both effects are statistically insignificant. This suggests that, controlling for household characteristics, financial inclusion of household members, electricity attributes at the community level and sector fixed effects, being in an urban area has no effect on households' WTP for electricity.

Table 5.12 - Regression results: willingness to pay for electricity.

	Willingness to pay for electricity			
	One-time payment		Instalments	
	(1)	(2)	(3)	(4)
Household characteristics				
Monthly income	7.074***	8.908**	1.108	5.024*
	(0.729)	(0.939)	(0.510)	(0.815)
Household education	1.043	1.061	1.025	1.092
	(0.070)	(0.126)	(0.045)	(0.092)
Sex of head of household	0.784	0.399	2.102*	1.917
	(0.659)	(1.018)	(0.388)	(0.633)
Age of head of household	0.992	1.012	0.968**	0.960*
	(0.016)	(0.024)	(0.016)	(0.024)
Financial inclusion				
Household members with bank account	1.744	2.409	2.277**	2.770
	(0.602)	(0.973)	(0.378)	(0.743)
Access to credit/loans	1.616	1.783	4.757***	8.879***
	(0.304)	(0.672)	(0.410)	(0.693)
Uses mobile money	3.935**	8.517**	2.487	9.540*
	(0.637)	(0.943)	(0.654)	(1.126)
House ownership	0.220*	0.096	4.114**	3.406
	(0.875)	(1.525)	(0.644)	(1.571)
Electricity attributes				
Reliability of electricity	11.087**	0.075**	0.795	0.800
	(1.025)	(1.176)	(0.694)	(0.649)
Quality of electricity	2.414*	1.832	2.507	3.245**
	(0.495)	(0.576)	(0.668)	(0.491)
Availability of electricity	0.588	4.418*	3.715***	0.777
	(0.366)	(0.813)	(0.457)	(1.220)
Locality (reference category: Rural)				
Urban	0.463	0.367	1.986	2.067
	(0.642)	(1.365)	(0.511)	(0.970)
Intercept	0.00001***	0.000***	0.037	0.0005*
	(3.375)	(4.415)	(2.374)	(4.167)
Sector fixed effects	No	Yes	No	Yes
Household characteristics	Yes	Yes	Yes	Yes
Financial inclusion	Yes	Yes	Yes	Yes
Locality dummy	Yes	Yes	Yes	Yes
McFadden's pseudo R-squared	0.27	0.48	0.28	0.55
Observations	607	607	516	516

Note: *p<0.1; **p<0.05; ***p<0.01
Coefficients reported are odds ratios instead of log odds (standard errors and p-values are unchanged).

5.4 Discussion

From the initial exploration of the data, there are clear differences between levels of electricity access across the different habitats. However, these differences could be accounting for factors that are specific to households or communities. We have seen that income, for example, varies across habitats. So does level of education and distance from urban centres. Some of the differences in levels of electricity access in the different habitats, therefore, cannot be attributed purely to the habitat that a household is in. In the analysis, different household, community, demographic, and regional characteristics are added to the estimation exercise.

The results from estimating Equation (5.1) show that there are differences in the likelihood of households having access to electricity across the different habitats. In the base model, the odds for a household in an isolated rural area, the reference category, of having access to electricity is 0.105. The coefficients for all the habitat dummies are positive, which shows that isolated rural areas have the lowest rate of electricity access. Controlling for Locality, whether a household is a rural or urban area (Column (2), Table *5.8*), significantly reduces the likelihood of households in unplanned urban areas and modern urban areas having access to electricity. Without considering household and community characteristics, urbanicity has a large significant effect on household's likelihood of access. This is corroborated by the results in Table *5.9*, where in the base model (Column (1)), households in urban areas are 22 times more likely to have access to electricity than households in rural areas, and by Figure *5.3* in Section 5.2.1, which shows that a much higher percentage of households in urban areas have access to electricity.

Centralisation has an effect on households in certain habitats. Column (5) in Table *5.8* shows the results of the estimation after controlling for locality, household and community characteristics, and population density. Adding the centralisation variable, whether a household is in Kigali province, in Column (6), has a negligible impact on households in Umudugudu and unplanned rural areas, but reduces the likelihood of households in unplanned urban areas by 59.5 percentage points. This shows that being in Kigali province, and controlling for locality, household and community characteristics, has no effect on the likelihood of households in Umudugudu and unplanned rural areas having access to electricity. Furthermore, Column (6) in Table *5.8* shows that, after controlling for locality, household and community characteristics, population density and centralisation, households in Umudugudu are 149% more likely to have access to electricity than isolated rural areas, while households in unplanned urban areas are 133% more likely to have access to electricity (a difference of 16 percentage points). Column (7) introduces sector fixed effects[24]. In this final model, households in Umudugudu are 121% more likely to have access to electricity than households in isolated rural areas, 7 percentage points higher than for households in unplanned urban areas and 15 percentage points higher than households in unplanned rural areas. The coefficients for households in old resettlements and modern urban areas are unintuitive. This is likely due to the small number of households in these areas in the sample.

Given that the estimation uses isolated rural areas as the reference habitat category, and that the estimation controls for locality and several household and community characteristics, a certain level of homogeneity is assumed across households, and the coefficients of the habitat variables in Column (7) in Table *5.8* are interpreted as follows. The coefficient of the unplanned clustered rural housing dummy is interpreted as the effect of clustering. The coefficient of the Umudugudu dummy is interpreted as the effect of government planned clustering. And the coefficient of the urban unplanned dummy is interpreted as the effect of living in an urban area beyond official area designation. Therefore, clustering increases the likelihood of households having access to electricity by 107%. And the effect of clustering in an urban area is interpreted as the difference between the coefficients for the unplanned urban variable and unplanned rural variable: a positive difference of 8 percentage points. Finally, the effect of government planned clustering, interpreted as the difference between the coefficient for Umudugudu and unplanned rural area, is 15 percentage points. Meaning that the likelihood of households in Umudugudu of having access to electricity is 15 percentage points higher than households in unplanned rural areas. The difference in likelihood for households in Umudugudu versus households in unplanned urban areas is an increase of 7 percentage points.

[24] This model does not control for centralisation and population density of the sector.

The results of the estimation in this chapter thus far show that households in planned government settlements, controlling for household and community characteristics, locality and sector fixed effects, are more likely to have access to electricity than households in unplanned rural areas and unplanned urban settlements. This is an important outcome. It shows that, ultimately, the government's settlement policy, with its various objectives, has had a positive effect on electricity access. More noteworthy, given that one of the many objectives of the settlement policy was to house returnees and provide land to low-income households, it is more likely for a returnee family or a low-income household to have access to electricity in a government planned settlement than in an urban area.

The results from Table *5.8* are supported by the results from estimating Equation (5.1) where the main explanatory variable is locality, whether a household is in an urban or rural area, presented in Table *5.9*. The base model (Column (1)) shows that households in urban areas are 22 times more likely to have access to electricity than households in rural areas. Controlling for household and community characteristics, population density and centralisation, the difference in likelihood decreases significantly. In the final model, which controls for sector fixed effects, households in urban areas are only 18% more likely to have access to electricity than households in rural areas and this difference in likelihood is not statistically significant. This is further evidence that urbanicity is not a significant factor in determining households' likelihood of having access to electricity.

In the model with an interaction term (Table *5.10*), controlling for household and community characteristics, within Kigali province, a household in an urban area is 8.5 times more likely to have access to electricity than a household in a rural area. Surprisingly, the Kigali variable, which measures the effect of being in a rural area in Kigali versus a rural area not in Kigali, is negative.[25] For rural households being in Kigali versus not, reduces the odds of access to electricity by 5%. These results suggest that households in rural Kigali, when compared to

[25] Because Kigali province is made up of 30 sectors, to avoid errors introduced due to a nesting structure in the estimation, the Kigali coefficient of the third estimation with sector fixed effects is not discussed.

urban households in Kigali and their counterparts in the other four provinces, are the most deprived. This is consistent with the results of the estimation of Equation (5.1) in Table *5.8*, where the introduction of the Kigali variable in Column (6) has almost no effect on the odds of households in Umudugudu or unplanned rural areas of having access to electricity. After including sector fixed effects, the Locality variable, which measures the effect of being in an urban area versus a rural area for households not in Kigali province, has no effect on households' likelihood of access to electricity. This suggests that outside of Kigali province, households in urban areas are equally deprived as those in rural areas.

The effects of living in a certain habitat, locality, or region on the likelihood of having access to electricity have been established. Households' willingness to pay (WTP) for electricity using two different payment methods is explored to look at other drivers influencing households' access to electricity. Unsurprisingly, household income has a positive effect on WTP for electricity for both payment methods, while the education level of household members has no statistically significant impact. The age of the head of the household has no impact on WTP a one-time payment and a negative effect on WTP in instalments, where a one year increase in the age of the head of the household reduces WTP by 4%. Access to credit has a positive effect on WTP in instalments and the use of mobile money has a positive effect on WTP using both payment methods. Certain attributes of electricity provision at the community level also affect households' WTP. Surprisingly, households in communities with reliable electricity are less likely to be willing to pay a one-time payment for a connection. While good quality electricity provision at the community level has a positive effect only on WTP in instalments. Being in a community with electricity generally available during the day has a positive effect on WTP a one-time payment and no effect on paying in instalments. More relevant to the results of the previous models, being in an urban area has no significant impact of households' WTP for an electricity connection. For WTP through a one-time payment, being in an urban area reduces the odds of WTP by almost 65%.

These results suggest that, left to their own devices, even with financing options, there are multiple, sometimes unintuitive, factors that influence households' willingness and ability to get access to grid electricity. For example, household education has no impact on household’s WTP for a grid connection despite the fact that, controlling for income and other household and community characteristics, a one-year increase in education increases the odds of having access to electricity by 24% (Table *8.10*, Appendix C). And the quality, reliability, and availability of electricity at the community level have varied effects on households’ willingness to pay. An intuitive assumption is to think households might be motivated to invest in an electricity connection if they see the benefits around them. One potential explanation for these results is that, in both urban and rural areas, houses tend to cluster in areas with households that have similar characteristics. So, it is likely that the measures of reliability, quality and availability at the community level do not capture these same attributes at the neighbourhood level. For example, a household in a neighbourhood where electricity is available but unreliable, is not likely to see the benefits of reliable electricity, even if it is reliable in a different neighbourhood close by, and, therefore, would not be motivated to make such a large financial commitment.

Nonetheless, the existence of electricity at the community level has a large positive effect on the likelihood of households having access to electricity. Despite some households’ unwillingness or inability to pay for a grid connection, having the option matters. Households in electrified communities are 14 times more likely to have access to electricity, even when controlling for sector fixed effects (Table *8.10*, Appendix C).

Thus, the findings of this chapter provide evidence of the importance of country context in analysing how governments provide electricity. Rwanda’s rapid increase in electricity access is both deliberate, given its existing and previous electrification strategy, and a consequence of a housing policy that created clustered settlements for unrelated reasons.

Several examples of positive policy programmes increase access to modern fuels for low-income households. For instance, in Brazil, LPG was introduced in the late 1930s as a viable cooking fuel to decrease the use of traditional fuelwood. Similarly, the “Light for all” program, introduced in the 1990s, managed to extend the national electricity grid to over 10 million (Coelho and Goldemberg, 2013). Both programs, of course, were implemented in an environment and during a time that was conducive to their success. More specifically, an electrification program in Sao Paolo, Brazil, successfully provided electricity connections to shacks in Favelas (Patterson, Eberhard and Suarez, 2002). The total cost of the connection was subsidised, and the electricity, provided at a subsidised flat rate, was paid for monthly. The results were encouraging. Electric lighting made cleaning the house easier, eliminated indoor pollution and made taking care of children less stressful because of a reduced risk of fire accidents. The most significant consequence is that an electricity connection gave residents access to credit systems through their electricity bills, which contained all relevant personal information. There are examples of the success of slum electrification policies in East Asia. In Thailand, 100 % of slum residents have electricity, and most households use LPG for cooking. The high access to modern energy in slums is mainly due to a successful electrification program, house registration policies, price subsidies and low monthly electricity service charges for poor households (Shrestha *et al.*, 2008).

Equally, there are examples of ill-conceived policy programmes. In Dhaka, Bangladesh, almost all households in slum areas have access to electricity, but not all have individual meters. The local utility has set up pole meters that serve several homes and operates on a credit basis. The pole meter and electricity distribution are supervised by a community leader who oversees pricing. This doesn't usually work out in the residents' favour. This system, however, is seen as "better than nothing," as most households, even if they can afford the high upfront cost, wouldn't be able to get an individual meter because they would invariably lack the required legal documents. As a result, electricity connections are unreliable, more expensive and unsafe. For Dhaka, Lipu, Jamal and Miah (2013) have identified several barriers to electricity uptake in urban slums. An energy policy barrier exists in that government energy policy, effective since 1996, has not been tailored to cater to the urban poor. Government housing policies have failed to provide the urban poor with legal settlements, and as a result, they cannot get a metered electricity connection legally. In addition, there are no institutions tasked with taking care of or monitoring and evaluating electricity services to the urban poor. There are also losses in transmission and distribution associated with outdated infrastructure.

Conducive government policies must support efforts to provide modern energy services to urban slum residents. Several studies have emphasised the importance of policy in delivering reliable and affordable energy services in urban slums (see, for example, Lipu, Jamal and Miah, 2013; Mimmi, 2014; Lee et al., 2016; Runsten, Nerini and Tait, 2018)). For example, the failure of electrification agendas in Ghana in the past couple of decades can be attributed to a lack of coherent national policies, no priority for the urban poor population and no clear strategies or financing mechanisms (Kemausuor *et al.*, 2011). Some studies argue for subsidies to increase better energy services for underserved areas (Lee *et al.*, 2016). Another common policy criticism is that government departments concerned with energy service delivery and slum development are isolated from one another (see, for example, Lipu, Jamal and Miah (2013) for Bangladesh; Runsten, Nerini and Tait (2018) for South Africa).

It is also evident from the literature that energy access is not only dependent on electrification policies but also on housing policy, which determines the legal status of households in slums; infrastructure policies, which determine infrastructure development areas; and development policies, which target the urban poor (see, for example, Visagie (2008) for South Africa; Fall et al. (2008) for Senegal; Lipu, Jamal and Miah (2013) for Bangladesh; Mimmi (2014) for India).

6 Chapter 6: Conclusion

6.1 Background and research questions

6.1.1 Problem identification

Today, Africa is the least urbanised continent in the world. Most of the continent's future urban growth is predicted to occur in small and medium-sized cities (Awumbila, 2017). In developing countries, the internal movement of people from poorer to wealthier areas is a consequence of many factors. People tend to move from poorer to relatively more prosperous regions, but income alone cannot explain the process. Urbanisation has two different definitions. It refers to the movement of people from urban to rural areas and the number of people living in urban areas.

While economic conditions play a crucial role in migration (Stark and Bloom, 1985; Black *et al.*, 2011), other factors, such as political instability (Davenport, Moore and Poe, 2003), infrastructure availability (Awumbila, 2017) and population density (Hugo, 2011), play a part too. Consequently, the process of urbanisation changes household structures (Black *et al.*, 2011; Hugo, 2011) and in urban areas families tend to become smaller and live in closer proximity to one another (Njoh, 2003). Environmental effects on migration act through climate variability, specifically through changes in rainfall patterns (Barrios, Bertinelli and Strobl, 2010) and crop yields (Lilleor and Van den Broeck, 2011).

The factors that determine urbanisation will ultimately influence service provision in urban areas. The urbanisation process demands the development of critical infrastructure to accommodate the needs of an increasingly urban population. Energy provision has a well-established positive relationship with economic growth and is a vital ingredient for successful industrialisation (Stern, 2004; Chontanawat, Hunt and Pierse, 2008; Odhiambo, 2009; Odularu and Okonkwo, 2009; Belke, Dobnik and Dreger, 2011). Additionally, whether these services are provided and how they are used also depends on specific economic, institutional and demographic factors.

The relationship between urbanisation and energy consumption has been studied extensively. The first investigations of the relationship between urbanisation and energy consumption came to a similar conclusion: urbanisation increases energy consumption. The argument is that as more people move to urban areas, energy consumption increases through increased economic activity, increased use of modern energy – either electricity or energy-intensive transport – and the subsequent adoption of energy-intensive lifestyles. Some of the findings in the literature on the subject results can be attributed to the data, choice of explanatory variables, or the model used. It is also generally recognised that the data doesn't usually tell the whole story and that context matters.

One study on China identifies three pathways through which urbanisation affects energy consumption: urban spatial expansion, urban motorisation and energy-intensive (Zhao and Zhang, 2018). It is fair to expect these pathways to have other implications in the Sub-Saharan African context: new urban residents, who are more likely to be urban poor, settle into modest housing; the increase in urban motorisation would more likely drive demand for public transport than car ownership; and whether migrants adopt energy intensive lifestyles will depend on where they settle and whether they have access to the grid and other energy services. Studies on the relationship between urbanisation and energy consumption in Sub-Saharan Africa are limited in their number and scope. The two studies identified in the literature only look at Angola (Solarin and Shahbaz, 2013) and Ghana (Adom, Bekoe and Akoena, 2012). Like the remainder of the literature, these studies only consider the demographic (urbanisation included) and economic drivers, with no consideration for the effects of governance on energy consumption.

The delivery of public services depends on institutional quality. A lot of the literature suggests a positive correlation between institutional quality and public service provision (see, for example, McGuire and Olson, 1996; Lake and Baum, 2001; Adserà, Boix and Payne, 2003; Deacon, 2003; Brown, 2006; Rothstein and Teorell, 2008; Harding and Stasavage, 2014)). There is, however, some suggestion that better institutions are not always the answer. A growing literature on the effect of institutional health on the provision of public services and infrastructure projects in developing countries shows mixed results: no significant relationship between democracy and infrastructure project efficiency (Isham, Kaufmann and Pritchett, 1997), no relationship between quality of governance and energy related infrastructure (Onyeji, Bazilian and Nussbaumer, 2012), and negative relationship between democracy and administrative capacity for nascent democracies (Bäck and Hadenius, 2008).

While there is some evidence to suggest a positive relationship between institutional quality and electricity consumption (Ahlborg *et al.*, 2015), this means that low-income countries with low levels of democracy, even with genuine democratisation, cannot expect to have well-functioning, efficient governments and therefore should not expect much with regard to infrastructure projects or service provision. Furthermore, electricity is commonly used as a political tool and can be manipulated to influence the outcome of elections (Baskaran, Min and Uppal, 2015). Similarly, there is evidence of aid distribution for political gain by ruling parties during or prior to elections in Sub-Sharan Africa (Briggs, 2012). Governments acting under electoral constraints are keen to show their commitment to service provision to win votes. Unlike democracies, more autocratic governments, and their policies regarding public service provision, are not constrained by electoral processes.

Nonetheless, it is in the interest of an authoritarian leader to provide services, at least to limit any political threats and maintain a functioning economy. If responding to the incentives they face, autocratic governments are more likely to prioritise urban residents over industrial consumers. Furthermore, electricity provision to the industrial sector drives industrialisation and economic growth (Rud, 2012; Andersen and Dalgaard, 2013). Like most other public services, most of the electricity infrastructure in Sub-Saharan Africa is centralised and bundled. Governments have a monopoly over electricity supply and investment in electricity infrastructure (Brew-Hammond, 2010; Foster and Briceno-Garmendia, 2010). For democratic governments, allowing private sector participation in the power sector frees up portions of the budget that can be spent elsewhere, such as health and education. Autocratic regimes are more inclined to support infrastructure investment, which present opportunities for corruption and rewarding supporters. If these projects target urban areas, both the urban elite and industrial sector might benefit. The impact for low-income households is not clear, especially since they tend to live in areas with no access to the grid, even in urban centres.

Energy access for low-income households in both rural and urban areas is hindered by several factors: no strategic and long-term planning; structure of settlements limiting access to modern fuels; high upfront costs of clean technologies; limited institutional support and engagement; ineffective subsidies (GNESD, 2008). There are plenty of factors that influence a household's use of electricity: demographic characteristics and proximity to markets and urban centres (Rahut *et al.*, 2017), energy policy targeted at low-income areas (Dhingra *et al.*, 2008), and city-level policies (Gulyani, Bassett and Talukdar, 2014). One significant demand-side barrier to modern energy access in urban slums is affordability. Poor households, on average, pay a larger portion of their income for low-quality energy services (Scott, Dunn and Sugden, 2003), are more likely to use less financially efficient traditional fuels (Foster, 2000), and not be able to use modern services even if they have access (Visagie, 2008). As a result, some households that reside in areas where electricity is available, resort to extension cords and are, therefore, subjected to the associated uncertainties of unreliable supply, the danger of electrocution and unpredictable rates. And having a higher income does not necessarily protect households from being energy poor (Shahidur R. Khandker, Barnes and Samad, 2012).

This highlights the importance of energy policy in ensuring access to energy services for the most vulnerable households. Moreover, institutional factors play a role in energy service provision in urban and rural settlements, either through pro-poor policies prioritised by left-leaning governments (Aklin *et al.*, 2015) or the political will of state-level governments (Runsten, Nerini and Tait, 2018). A gap in the contextual understanding of low-income areas (Fall *et al.*, 2008) and the exclusionary nature of government electrification projects in low-income neighbourhoods (de Bercegol and Monstadt, 2018) are a major impediment to successful modern energy access efforts. In many ways, the availability of an electricity supply doesn't imply access, and access doesn't imply use. If, for example, a house is located within proximity of the grid, it is not guaranteed access if connection fees are high, and a connection doesn't guarantee use if tariffs are high (Reddy, 2015).

There are examples of government policies that had a positive impact on energy access for low-income households: the LPG distribution and the “Light for all” grid extension programmes in Brazil (Coelho and Goldemberg, 2013), and an electrification programme in parallel with house registration policies in Thailand (Shrestha *et al.*, 2008). There are also examples of badly designed programmes: Dhaka’s slum electrification programme failed to afford a meter for each household and relied on local community leaders to distribute electricity (Lipu, Jamal and Miah, 2013). The importance of government policy cannot be overstated. But it is also important to ensure coherence between different government policies (Kemausuor *et al.*, 2011) and the commitment across different government departments (Runsten, Nerini and Tait, 2018). Finally, there is evidence that the success of electrification and energy access programmes depend on housing, infrastructure, and development policies (Visagie, 2008); Fall et al., 2008; Lipu, Jamal and Miah, 2013; Mimmi, 2014).

6.1.2 Research questions

Based on the problems identified above, this thesis asks three main research questions. Research question 1 asks: what is the effect of urbanisation on energy and electricity consumption in Sub-Saharan Africa? Based on a review of the literature and the structure of Sub-Saharan African economies, a hypothesis is presented arguing that urbanisation would have a positive effect on total energy consumption and no effect on electricity consumption. Based on the findings from the first research question, research question 2 asks: what is the relationship between governance and urban electricity access in Sub-Saharan Africa? Informed by the literature on governance and public service provision, the main proposition was argued as follows: democratic governments are subject to electoral constraints and would therefore prioritise rural electrification; while autocratic governments, acting under the threat of regime change from urban elites, prioritise urban electrification. Finally, based on the exploratory findings of the second research question, research question 3 asks: what is the effect of government policy on electricity access for low-income households?

6.1.3 Answering the research questions

The thesis first establishes an evidence base on the dynamics between urbanisation and energy consumption in Sub-Saharan Africa at the aggregate level using country-level data on energy and electricity consumption and urbanisation. Then, using a mixed methods approach, first with country-level data, then project-level data and case studies, provides evidence on the relationship between governance and electricity access in both rural and urban areas in Sub-Saharan Africa. Finally, using household-level data, this thesis investigates how government policy affects electricity access at the household level.

The first research question is tackled by estimating static and dynamic econometric models using data from the World Bank World Development Indicators database, the International Energy Agency and Freedom House governance data to find the relationsip between urbanisation and energy consumption in Sub-Saharan Africa. To answer the second research question, first, data from different databases on quality of governance, Freedom House, the World Bank's World Governance Indicators and the Polity IV project, along with data from the World Bank's World Development Indicators, are used to find the macro-level relationship between governance and electricity access. Then, using project level data compiled by the author from three main databases, the World Bank's Projects and Operations database, the World Bank's Public Participation in Infrastructure database and the World Resource Institute's Global Power Plants Database, the effect of governance on which areas are targeted by power projects and grid extension investment is established. Finally, using country case studies, mainly Togo, Benin, Gambia and Ghana, qualitative evidence is provided in support of the empirical evidence on the relationship between governance and electrification. To answer the third research question, a new survey dataset on household electricity access in Rwanda is used, and the richness of the dataset, which includes details on habitats, household and community characteristics, is exploited to estimate the impact of the Rwandan government's housing policy on households' likelihood of having access to electricity.

6.1.4 Main findings

The results of Chapter 3, which tackles research question 1, show that urbanisation has a positive and significant effect on total energy consumption and no significant effect on total electricity consumption. The results support the two hypotheses presented in the chapter. The first hypothesis argued that urbanisation should have a positive effect on total energy consumption. The premise of the hypothesis is based on the argument that as more people move to urban areas, increases in income are expected to translate to increases in the use of modern energy and technologies and an increase in the use of less efficient traditional fuels. The second hypothesis argued that urbanisation should have no significant effect on total electricity consumption. This argument is based on the understanding that rural-urban migrants are relatively poor and are, therefore, more likely to reside in urban areas where access to electricity is limited and are less likely to be able to afford both the upfront cost of a connection to the grid and regular consumption of electricity, even if it's available. Furthermore, the likelihood of having access to electricity for rural-urban migrants is further reduced by the fact that grid expansion has not kept up with urban population growth.

The results of the first part of the investigation in Chapter 4, which answers research question 2, show the existence of a negative relationship between governance and urban electricity access. The results support the research proposition presented in the chapter, which makes two main arguments. First, given that democratic governments are subjected to electoral constraints, public service provision, of electrification is an effective and verifiable option, is one way of securing votes. And given that in Sub-Saharan African countries, most the population is rural and poor. Democratic governments will prioritise rural electrification. On the other hand, autocratic governments are not constrained by elections. Urban residents pose the biggest political threat to autocratic governments. Because electricity is a useful political tool, autocratic governments prioritise urban electrification. The second set of results from Chapter 4 show that a 1 unit increase in quality of governance (on a 5-point scale) is associated with only a 5% probability that a power project is implemented to serve an urban area. This means that governments with good quality of governance ratings are much more likely to extend electricity to rural areas. Finally, the case studies show how democratic transitions shift the electrification priorities of governments. In the first pair of case studies, Benin and Togo take divergent paths to governance and experience different levels of rural and urban electrification. In Gambia, a democratic transition shifts the electrification priorities of the central government, supported by governance-conditioned finance from international financial institutions. In Ghana, a decade of democracy has a significantly positive impact on rural electrification.

The results of Chapter 5, which answers research question 3, show the importance of government policy in increasing access to electricity for low-income households in Rwanda. The findings show that government planned settlements are more likely to have access to electricity than unplanned habitats in both rural and urban areas, controlling for household and community characteristics, population density, centralisation, and sector fixed effects. The findings also show that, in Rwanda, centralisation, living in the central Kigali province, has no impact on the likelihood of households in government planned settlements or unplanned rural settlements. And urbanicity has no effect on households having access to electricity, when controlling for household and community characteristics and sector fixed effects, even for households in the central Kigali province. Finally, the results of the analysis on willingness-to-pay shows that, similar to the findings in the literature, the most important aspect of households' willingness to pay for an electricity connection are related to income and access to financial services, such as a bank account, mobile money or credit. And that households in urban areas are no more likely to be willing to pay for an electricity connection than their rural counterparts.

Taken together, the findings of this thesis point to the importance of aligning energy policy with other development and infrastructure expansion policies. That urbanisation has no effect on electricity consumption points to the access and affordability constraints of urban households. And given that more democratic governments are more likely to electrify rural areas and the established relationship between electricity consumption and economic growth, under the incentive of gaining votes and severe budget constraints, it's likely the democratisation process delays expansion in urban electrification and, as a secondary effect, might hinder growth prospects. Finally, the expansion of rural electrification favoured by politicians acting under electoral constraints can benefit from other government policies, such as Rwanda's housing and settlement policy, which, through clustering, increased the likelihood of low-income households having access to electricity.

6.2 Wider implications of results

This thesis has investigated the relationship between urbanisation and energy consumption, the relationship between governance and electricity access, and the effect of government policy on household access to electricity. As outlined below, the findings have implications for research and policy concerning energy provision in Sub-Saharan Africa.

The results in this thesis have several implications for energy, infrastructure and development policy in Sub-Saharan Africa. The thesis first examines the relationship between urbanisation and energy consumption in Sub-Saharan Africa. There are two major findings with wider policy implications. First, the effect of urbanisation on total energy consumption is positive and significant. This means that as people move from rural to urban areas there is an increase in the demand for, and ability to acquire, energy services. Second, urbanisation has no significant effect on electricity consumption. This means that an increase in the number of people living in urban areas does not increase electricity consumption. Given the Sub-Saharan African context, where most urban residents are poor and most households practice fuel stacking, these findings mean that: first, the expansion of the electricity infrastructure is not keeping up with the increasing urban population. Therefore, new urban residents will have to use other types of energy to satisfy their energy needs. Second, the positive relationship between urbanisation and electricity consumption means that there is a need for energy infrastructure to keep up with the need of an increasing urban population. Governments will, at the minimum, have to ensure the timely and efficient provision of fossil fuels for transport, charcoal for cooking and electricity for those are able to afford it. The need for better infrastructure is now more urgent given the growing threat of climate change and its impact on migration and vulnerable communities.

The findings from Chapter 4 that a positive relationship between quality of governance and rural electrification and a negative relationship between governance and urban electrification adds to the existing literature on the subject. This means that democratisation incentivises politicians to prioritise rural areas and electrification strategies that bring in more votes. Given the budget limitations of governments in Sub-Saharan Africa and the importance of the industrial sector to economies across the continent, there may be a case for prioritising urban electrification. While rural electrification has proven benefits for low-income rural households, the impact on development and economic growth is yet to be established. This evidence gap could perhaps be explained by the difficulty of measuring the effect of electricity access to low-income communities on the wider economy.

Having said that, given the size of local economies in rural areas, where sometimes even grid extension is not enough to guarantee a grid connection, consumption levels in rural households will be limited by affordability constraints. And if grid expansion occurs in isolation of other policies and infrastructure expansion projects, the positive impacts of electricity will be subdued. For example, consider the case of a milling shop in a rural village that uses a wooden pestle and mortar to grind grain. If the village is then connected to the grid, the shop owner might only be able to acquire a milling machine that runs on electricity if they have access to finance. Even then, if the owner manages to acquire a machine, through finance or other means, the benefits of the increase in productivity of the shop, in the absence of other infrastructure, such as a more connected road network, will not be realised if the market the shop operates in is limited to the village within which the shop had already existed. The importance of coherent government policy is evidenced by the findings of Chapter 5.

The findings in Chapter 5 point to the importance of targeted infrastructure and expansion in line with other policies, such as housing and settlement policies and broader development policies. These findings contribute to the literature on the impact of government policy on energy access for low-income households. For example, the positive effect of housing policies on electrification in Thailand and the spill-over effects of electricity expansion on access to other services in Brazil's urban slums (Brazil urban slums). The finding that low-income households living in government planned settlements in Rwanda are more likely to have access to electricity than their counterparts in unplanned rural and urban areas demonstrates the benefits of targeted government policy. Rwanda's settlement policy specifically targets returnees and low-income households to solve the land scarcity issue. In addition to providing land for households, the government hoped (and, as this thesis shows, has indeed managed) this clustering could be used to provide low-income households with services. Improved access to services has a positive effect on wellbeing. This is also evident in the exploratory analysis in Section 5.2.1, where households in Umudugud tend to be better educated and have higher incomes than households in unplanned rural and isolated rural areas.

The necessity for caution in designing energy expansion policies and strategies is in line with new calls for more scrutiny over electricity expansion to underserved communities, where there is a risk for potential negative consequences, such as conflict and dispossession, if context is not considered.

6.3 Limitations

The findings in this thesis have several limitations. First, there are several data limitations. Both Chapters 3 and 4 use data on Sub-Saharan Africa from the World Bank's World Development Indicators database. The data in this database is collected from several sources: Demographic and Health Surveys, Living Standards Measurement Surveys, Multi-indicator Cluster Surveys, World Health Surveys, and other national developmental and implemented surveys, and various government agencies. This approach, while comprehensive, is problematic for Sub-Saharan Africa because of the low statistical capacity of country statistical bureaus and government agencies (Jerven, 2013). To fill in gaps in the data, the World Bank uses country and regional averages. For example, even for countries with no data points, a weighted regional average is used as an estimate. Furthermore, the power projects dataset compiled by the author and used in Chapter 4 is small (138 observations for power projects and

60 observations for transmission and distribution projects). The number of observations in the dataset is a direct consequence of the time constraints.

Second, there are several shortcomings with using the World Bank's governance indicators. For example, quantifying perceptual assessments is difficult and can be inherently biased: reliance on experts and sectoral leaders from developing countries who are more likely to have had similar training; bias towards countries that are exhibiting good economic performance; bias towards more Western ideals of good governance (Norris, 2008a). Some have argued that the World Bank's governance indicators lack precision (see, for example, van de Walle (2006) and Brewer, Choi and Walker (2007), and Langbein and Knack (2010) contest the foundations on which the indicators are built. For example, the type of corruption being measured (Control of corruption), or the assumption that protecting markets from politics is a good thing (Rule of law). Furthermore, good governance is a fluid concept with several connotations, meanings, and potential quantifications (Kaufmann, Kraay and Mastruzzi, 2010). When compared to the conventional, more popular democracy indicators, such as Freedom House and Polity IV, the governance indicators are "under-theorised" (Norris, 2008b) and the limited number of annual observations limits their usefulness. Having said that, today the World Bank's six governance indicators are some of the most widely used governance indicators. One major advantage is the flexibility afforded by six different indicators measuring different aspects of governance. For example, Onyeji, Bazilian and Nussbaumer (2012) use only regulatory quality and government effectiveness to measure the effect of institutional quality on total electricity access.

Third, the data on electricity access has some limitations. The most noticeable difference between the two datasets on electricity access used in Chapter 4 is their respective definitions of electricity access. Aklin, Harish and Urpelainen (2018) define electrification as households with access to grid electricity, and, accordingly, exclude households that are connected to microgrids or other distributed power systems. At first, this definition seems more suitable for the purpose of this research. Access to grid electricity is a better indicator of government efforts to provide electricity. Off grid systems can have other motivations. For example, private sector firms, using anchor models, could provide electricity to surrounding communities to recoup costs (Ramchandran, Pai and Parihar, 2016); community members can decide together to invest in an off-grid system; or NGO's or research institutions working on electrification could provide rural or urban households with access to a microgrid or solar home system (for example, see Bahaj et al. (2019) and Vernet et al. (2019)).

Another difference is the way each database deals with missing data. The World Bank uses regional averages to impute missing data when there are no baseline data points. On the other hand, Aklin, Harish and Urpelainen (2018) use percentages of rural and urban populations to fill in the gaps, and only when at least two of the set of three electricity access observations per country per year are available. The World Bank's database is more comprehensive in terms of time span and number of countries, but there are problems regarding consistency. For example, Table 6.1 below shows urban electricity access rates for Togo from different sources. The table shows the values quoted in the document, the reference for the values and the values from the World Development Indicators database. The two World Bank documents don't reference the World Bank. And, on average, there is a significant difference between the quoted values of urban electricity access in the documents and the World Bank database.

Table 6.1 - Different urban electrification rates in different documents for Togo.

			Urban electricity access (%)	
Document	Year	Referenced source	In the document	World Bank database
Togo Energy Sector Policy Review (World Bank, 2013b)	2011	CEET 2011 Annual Report	30	77.9
Project Appraisal Document: Togo Energy Sector Support and Investment Project (World Bank, 2017)	2015	No reference	56.4	84.4
Off-grid Solar Market Research for Togo (Lighting Global, 2018)	2017	World Bank	80	88.8
Demographic and Health Survey (Ministry of Planning Development and Spatial Planning (MPDAT), Ministry of Health (MS) and ICF International, 2015)	2015	No reference	83	84.4

Finally, there are some limitations related to the survey dataset used in Chapter 5. The analysis could not make full use of the richness, and main design purpose, of the dataset because of the skewness of the distribution of tier-levels of households. Most households have low tier ratings. Furthermore, there are general data accuracy concerns for measuring income using surveys (Randall and Coast, 2015). The length of the MTF survey (42 pages) introduces some doubt regarding the accuracy of the data collected. And, because the sample size was limited to 3,295 households and the need for a representative sample, there is a significantly lower number of households in modern urban areas and old settlements, which might affect the accuracy of the estimated coefficients.

6.4 Future research

While this thesis has provided evidence of the impact of urbanisation on energy and electricity consumption in Sub-Saharan Africa, the prioritisation of different governance structures for rural and urban electrification, and the importance of government policy for electricity access for low-income households, there is room to better understand the energy consumption needs of rural-urban migrants and how governments make decisions and finance infrastructure expansion to satisfy those needs.

A better understanding of the consumption habits of new urban residents can be done through longitudinal, qualitative research on the energy consumption at the household level. This way, a more contextual understanding can be gained of where new urban residents settle, the services available to them and the role the government plays in providing those services. A longitudinal study can shed light on how consumption habits change over time in the absence, or existence, of new energy infrastructure. It would also allow for researchers to track which areas are prioritised by governments and how these priorities change with institutional changes.

To better understand government decisions on infrastructure expansion for low-income households, a more in-depth study on project financing can be conducted. Further research could examine the terms with which financing is made available to governments, the priorities set by the government versus the requirements of financing agencies, and how these dynamics work under different types of regimes. This research can make use of the World Bank's

Projects and Operations database, which includes detailed documentation of every step in the process of World Bank funded projects.

In summary, this thesis provides mostly empirical evidence of trends in energy consumption and access at the macro-, project- and household-level. The thesis sheds light on the importance of governance and government policy in electricity provision. These findings provide an opportunity for researchers to conduct more qualitative research on the consumption habits of rural-urban migrants, the key drivers behind government decisions to expand electricity access and the tools available at their disposal, both locally and globally.

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8 Appendices

8.1 Appendix A – Supplementary material for Chapter 2

Table *8.1* shows the frequency of explanatory variables used in the literature of the effect of urbanisation on energy consumption.

Table 8.1 Frequency of explanatory variables used models in the literature.

Explanatory variable	**Frequency in literature**
Urbanisation	All
Income/economic growth/GDP per capita	All
Share of industry	23
Population	21
Industrialisation	9
Energy intensity	6
Share of services	4
Trade openness/liberalisation	3
FDI	3
Exports (and imports)	3
Car ownership/number of cars	3
Age ranges	3
Gross fixed capital formation	3
Energy efficiency	2
Rural income	2
Rural/urban setting	1
Structure of energy consumption	1
Urbanisation rate	1
Share of agriculture	1
HDI	1
Industry efficiency	1

Table 8.2 - Literature on urbanisation and energy consumption.

Author	Data set	Countries	Method (Model)	Variables	Relationship
(Jones, 1989)	1980	59 developing countries	Cross-sectional regression analysis	Dependent: energy use (modern and total) per capita, energy use (modern and total) per dollar of GDP. Explanatory: income per capita, industry share of GDP, urbanisation, arable population density, product-specific fuel prices	1% increase in urbanisation increases energy consumption by 0.35% to 0.48%.
(Jones, 1991)	1980	59 developing countries	Regression analysis of cross-sectional data	Dependent: energy consumption. Explanatory: GDP per capita, urbanisation, industrialisation	Urbanisation increases energy consumption: 1% increase in urbanisation increases energy consumption by 0.48 (per dollar of GDP)
(Parikh and Shukla, 1995)	1965 – 1987	Developed and developing countries	POLS, FE	Dependent: energy consumption. Explanatory: GNP per capita, share of agriculture in GDP, population density, urbanisation	Urbanisation increases energy consumption
(Burney, 1995)	1990	93 developed and developing countries	OLS, random coefficients	Dependent: electricity consumption per capita. Explanatory: GNP per capita, population density, average years of schooling, share of industry in GDP, GDP growth 1980 – 1990, urbanisation	Urbanisation positively affects electricity consumption in the vast majority of countries
(Imai, 1997)	1980 & 1993	Countries with a population over 10 million in 1995	Weighted LS (population used as the weight)	Dependent: energy consumption per capita. Explanatory: urbanisation	Urbanisation increases per capita energy consumption (1% increase causes 4.41% and 3.99% increases in 1980 and 1993 respectively).
(Lariviere and Lafrancè, 1999)	1991	45 cities in Quebec (Canada)	Regression analysis	Dependent: annual electricity consumption. Explanatory: average inhabitant age, annual degree days below 18 degrees C, urban density, share of homes heated by electricity, land wealth per inhabitant	High-density cities use less electricity per capita than low-density cities. (the effect of urban density is more significant on gasoline use).
(York, Rosa and Dietz, 2003)	1995	138 countries	STIRPAT, OLS	Dependent: energy footprint. Explanatory: population, percentage of population aged 15-65, GDP per capita, share of industry in GDP, urbanisation, urbanisation rate, latitude (tropical / non-tropical)	Urbanisation increases the energy footprint.

Author	Data set	Countries	Method (Model)	Variables	Relationship
(Liddle, 2004)	1960 – 2000 (10-year intervals)	23 OECD countries	OLS, FE	Dependent: road energy use per capita. Explanatory: GDP per capita, urbanisation, share of population aged 20 – 39, population density, average household size	Urbanisation decreases per capita energy use
(Halicioglu, 2007)	1968 – 2005	Turkey	ARDL bounds, ECM, AIC and SBC and HQC to find lag length	Dependent: residential electricity consumption per capita. Explanatory: income per capita, residential electricity price, urbanisation rate	Long run: urbanisation causes residential electricity consumption
(York, 2007a)	1960 – 2000	14 EU countries	STIRPAT, Cross-sectional time series Prais-Winsten regression model, PCSE	Dependent: energy consumption. Explanatory: population, population over 65, urbanisation, GDP per capita	Urbanisation has a positive, monotonic effect on energy consumption.
(York, 2007b)	1971 – 2002	14 South and East Asian countries	Cross-sectional time series Prais-Winsten regression model, PCSE	Dependent: energy production. Explanatory: population, percentage of population between 15 and 64, GDP per capita (GDP per capita squared), urbanisation (urbanisation squared), industrialisation, share of exports in GDP, share of imports in GDP, debt service payments as percentage of GDP, FDI as percentage of GDP, gross capital formation as percentage of GDP	Energy production lowest in moderately urbanised countries, and highest in least and most urbanisation countries. Early urbanisation leads to improvements in energy efficiency, but excessive urbanisation leads to inefficiency.
(Liu, 2009)**	1978 – 2008	China	ARDL, factor decomposition model, ECM	Dependent: energy consumption. Explanatory: population, GDP, urbanisation.	Short run: unidirectional Granger causality from urbanisation to energy consumption. Long run: same.
(Mishra, Smyth and Sharma, 2009)	1980 – 2005	9 Pacific Island countries	Pedroni panel cointegration test, Granger causality, Panel long-run estimates	Dependent: energy consumption per capita. Explanatory: GDP per capita, urbanisation	Urbanisation increases energy consumption for the whole panel. 1% increase in urbanisation increases energy consumption by 2.41%.
(Poumanyvong and Kaneko, 2010)	1975 – 2005	99 countries	STIRPAT	Dependent: energy consumption, CO2 emissions. Explanatory: population, GDP per capita, share of industry, share of services, urbanisation, energy intensity (for CO2 only).	Urbanisation increases energy consumption in middle and high-income countries. The urbanisation elasticity of energy is highest for high-income countries. Urbanisation decreases energy consumption in low-income countries..

Author	Data set	Countries	Method (Model)	Variables	Relationship
(Jorgenson, Rice and Clark, 2010)	1990 – 2005	57 less developed countries	FD	Dependent: energy consumption. Explanatory: urbanisation, percentage of total population living in urban slums, population, GDP per capita, adult population, manufacturing as a percentage of GDP	Urbanisation positively associated with energy consumption. Percentage of population living in urban slums negatively associated with energy consumption.
(Liddle and Lung, 2010)	1960 – 2005 (5-year intervals)	17 developed countries	STIRPAT, Beck and Katz PCSE	Dependent: residential electricity consumption, residential energy consumption. Explanatory: GDP per capita, population, population aged 20-34, population aged 35-49, population aged 50-64, population aged 65-79, urbanisation, non-fossil fuel energy supply, electricity share of residential energy consumption, ratio of rail to road network, industrial energy intensity	Urbanisation has a significant positive impact on both residential electricity consumption and energy consumption
(Karathodorou, Graham and Noland, 2010)	1995	84 cities (42 countries)	OLS, Seemingly unrelated regression equations (SURE)	Dependent: car ownership per capita, fuel consumption per km, car km travelled per car per year. Explanatory: urban density, GDP, fuel price, road length per 1000 ppl, public transport seat-km per capita, car user cost per capita (1), urban density, GDP, fuel price (2), urban density, GDP, fuel price, car ownership per capita, fuel consumption per capita, road length, public transport seat-km per capita, average user cost of public transport trip, car user cost per car	Urban density negatively affects fuel consumption (through changes in car stock and distances travelled by car).
(Poumanyvong, Kaneko and Dhakal, 2012)	1975 – 2005	92 Low, Middle and High-Income Countries	STIRPAT	Dependent: transport energy, road energy. Explanatory: population, GDP per capita, urbanisation, services share of GDP.	Urbanisation has a positive effect on road energy use. 1% increase in urbanisation: 0.81% increase in low income, 0.37% increase in medium income, 1.33% increase in high income countries.
(Zhang and Lin, 2012)**	1995 – 2010	China (regional)	STIRPAT, FE, two-way FE, FGLS, linear regression with panel-corrected standard errors (PCSE)	Dependent: energy consumption, CO_2 emissions. Explanatory: population, GDP per capita, share of industry in GDP, share of services in GDP, energy intensity (for CO_2 emissions).	Urbanisation increases energy consumption (increase declines from Western to Central to Eastern regions).

Author	Data set	Countries	Method (Model)	Variables	Relationship
(Shahbaz and Lean, 2012)	1971 – 2008	Tunisia	ARDL bounds, VECM Granger causality, Ng-Perron unit root test	Dependent: energy consumption. Explanatory: GDP per capita, financial development, industrialisation, urbanisation,	Short run: no significant impact of urbanisation on energy consumption. Long-run: positive and significant. 1% rise in urbanisation increases energy consumption by 0.9%. .Energy consumption Granger causes urbanisation.
(Michieka and Fletcher, 2012)**	1971 – 2009	China	VAR Granger causality, (different criterion to decide the lag length: LR, FPE, AIC, SC, HQ)	Dependent: coal consumption, electricity consumption from coal sources. Explanatory: GDP, urbanisation, coal consumption (for electricity consumption), electricity consumption (for coal consumption)	Urbanisation Granger cause electricity consumption from coal sources
(Gam and Ben Rejeb, 2012)	1976 – 2006	Tunisia	ADF, PP, KPSS, Johansen cointegration test, Johansen and Juselius cointegration test, ECM, VAR	Dependent: electricity consumption. Explanatory: GDP, real electricity price, urbanisation, annual average temperature	Bi-directional causality between electricity consumption and urbanisation
(Fang, Miller and Yeh, 2012)	1981 – 2007	94 countries	IPAT, GMM estimator	Dependent: energy consumption. Explanatory: population, GDP per capita, urbanisation, ESCO (dummy variable)	Urbanisation reduces energy use
(Adom, Bekoe and Akoena, 2012)*	1975 – 2005	Ghana	ARDL bounds	Dependent: electricity consumption. Explanatory: GDP per capita, industry efficiency, structural changes in the economy, urbanisation, price of electricity, price of substitute fuel	Urbanisation increases electricity consumption. Long run: 1% increase in urbanisation increases electricity consumption by 0.62%. Short run: 1% increase in urbanisation increases electricity consumption by 0.33%
(Al-mulali, Binti Che Sab and Fereidouni, 2012)	1980 – 2008	7 regions	ADF unit root test, FMOLS	Dependent: energy consumption (urbanisation and CO2 emissions). Explanatory: urbanisation (energy consumption and CO2 emissions)	84% of countries have a positive long-run bidirectional relationship between urbanisation and energy consumption (and CO2 emissions). Some countries have negative long-run relationships: low-income countries (Zambia, Liberia, Ethiopia, Eritrea). Some countries show no relationship: low-income countries (Somalia, Chad). Countries with high urban population show more significant bi-directional long-run relationship than low-urban ones.

Author	Data set	Countries	Method (Model)	Variables	Relationship
(Zhou *et al.*, 2012)**	Depends on data	China	N/A	N/A	Urbanisation affects energy consumption in household, transportation and building materials industry.
(Zaman *et al.*, 2012)	1975 – 2010	Pakistan	ARDL, OLS, Wald test, Granger VECM	Dependent: electricity consumption. Explanatory: real GDP, FDI, population growth	1% increase in population growth increases electricity consumption by 1.605%. Short-run unidirectional causality from population growth to electricity consumption.
(Jiang and Lin, 2012)**	1978 – 2008	China	ADF and PP unit root test, Johansen-Juselius maximum likelihood method, Granger-Engle cointegration	Dependent: primary energy demand. Explanatory: GDP, share of heavy industry in GDP, urbanisation, energy efficiency, coal price index	Urbanisation increases energy demand.
(Solarin and Shahbaz, 2013)*	1971 – 2009	Angola	ADF, PP, Lee and Strazicich unit root test, Gregory-Hansen, ARDL bounds, VECM	Economic growth, urbanisation, electricity consumption	Urbanisation and electricity consumption Granger-cause each other. There exist long-run relationships between the three variables. Electricity consumption positively contributes to economic growth (except during the civil war).
(Al-Mulali *et al.*, 2013)	1980 – 2009	MENA countries	ADF, PP, Pedroni cointegration, Dynamic OLS, VECM	Energy consumption, CO_2 emissions, urbanisation	1% increase in energy consumption, 0.68% increase in urbanisation. 1% increase in urbanisation, 0.57% increase in energy consumption. Long run positive relationship more significant in high income countries. The relationship is negative in low income countries. Short positive one-way causal relationship from urbanisation to energy consumption. Significance of relationship depends on income and development levels.
(Sadorsky, 2013)	1980 – 2010	76 developing countries	Pooled estimators: POLS, FE, FE-IV, FD. Heterogeneous estimators (static and dynamic): Mean group (MG), Common correlated effects mean	Dependent: energy intensity. Explanatory: income, urbanisation, industrialisation.	Mixed results depends on estimation technique. Elasticities (long run): an increase in urbanisation of 1% increases energy intensity by 2.11% in the long run.

Author	Data set	Countries	Method (Model)	Variables	Relationship
			group (CCEMG), Augmented mean group (AMG)		
(Liu and Xie, 2013)**	1978 – 2010	China	ADF, PP, DF-GLS, Threshold cointegration test (Gregory and Hansen), TVECM	Dependent: energy intensity. Explanatory: urbanisation	Non-linear causal relationship between energy intensity and urbanisation. (investigate further)
(Wang *et al.*, 2014)**	1995 – 2011	China (provinces)	ADF-Fisher Chi-square, PP-Fisher Chi-square, Pedroni cointegration, VECM	Energy consumption, CO2 emissions, urbanisation	One-way positive causal relationship from urbanisation and energy consumption. A bi-directional positive causal relationship between CO2 emissions and urbanisation, and CO2 emissions and energy consumption.
(Ghosh and Kanjilal, 2014)	1971 – 2008	India	ADF, PP, ARDL, Johanes-Juselius maximum likelihood, Granger causality	Dependent: energy consumption. Explanatory: GDP per capita, urbanisation.	Unidirectional Granger causality: from energy consumption to economic growth, form economic growth to urbanisation.
(Liddle and Lung, 2014)	1971 – 2009	105 countries	Unit root test, Westerlund and Edgerton cointegration test, Canning and Pedroni Granger causality test, FMOLS	Dependent: sectoral electricity consumption (urbanisation) Explanatory: urbanisation (sectoral electricity consumption)	Electricity consumption Granger causes urbanisation
(Salim and Shafiei, 2014)	1980 – 2011	29 OECD countries	STIRPAT, ADF, PP, Breitung, LLC and IPS unit root tests, Fisher cointegration test, Johansen cointegration test, Granger causality, GMM estimation	Dependent: non-renewable energy consumption, renewable energy consumption. Explanatory: population, GDP per capita, share of industry in GDP, share of services in GDP, population density, urbanisation	Urbanisation positively influence non-renewable energy consumption. No causal relationship between urbanisation and non-renewable energy consumption. Population density has negative impact on non-renewable energy consumption. Only population has impact on renewable energy consumption. Unidirectional causality from non-renewable energy consumption to population density in the short run.
(Sun *et al.*, 2014)**	2013	1,200 households, China	ANOVA, Tobit, OLS	Dependent: total energy expenditure. Explanatory: sensitivity to tiered pricing in household electricity, use of solar energy, automobile ownership, household income, rural or urban	Rural or urban setting affects electricity expenditure. (rural electricity expenditure 17% lower than urban)
(Lin and Ouyang, 2014)**	2001 – 2011 (panel model)	30 provinces in China	RE, FE, 2SLS, ADF and PP unit root tests,	Dependent: primary energy demand. Explanatory: GDP, urbanisation, share	Urbanisation has positive impact on energy demand per capita.

Author	Data set	Countries	Method (Model)	Variables	Relationship
	1989 – 2011 (cointegration model)		Johansen-Juselius cointegration test	of industry in GDP, energy intensity, energy price	
(R Elliott, Sun and Zhu, 2014)**	1997 – 2010	29 provinces in China	AMG, Pesaran CD test, Pesaran CIPS test	Dependent: energy intensity. Explanatory: income per capita, industrialisation, provincial urban population to total population ratio, non-agricultural population to total population ratio, employment in non-agricultural sector to total employment ratio	Urbanisation has little or no short or long-term impact on energy intensity. Urbanisation has negative impact in the more developed Eastern region and sometimes positive impact on the Central and Western regions. The impact of urbanisation on energy intensity is sensitive to the econometric modelling approach.
(Shahbaz *et al.*, 2015)	1970 Q1 – 2011 Q4	Malaysia	STIRPAT, ARDL bounds, VECM	Dependent: energy consumption per capita. Explanatory: urbanisation per capita, real GDP per capita, real capital use per capita, real trade openness per capita.	Urbanisation Granger-causes energy consumption. Strong positive impact of urbanisation on energy consumption
(Zhou *et al.*, 2015)**	1990 – 2012	China (regional)	STIRPAT, FE, FGLS, Driscoll-Kraay standard errors (DK), Pesaran test	Dependent: energy consumption, CO2 emissions. Explanatory: urbanisation, share of secondary industry employment, share of tertiary industry employment, share of secondary industry in GDP, share of tertiary industry in GDP, farmland conversion, rural-urban income gap, energy intensity (for CO2 emissions).	Urbanisation increases energy consumption in the whole sample (same in the Central and Eastern regions) (insignificant in the Western region). Different magnitude results for FE, FGLS and DK models.
(Yan, 2015)**	2000 – 2012	30 provinces in China	POLS, FE, FGLS, PCSE, D-K	Dependent: energy intensity. Explanatory: urbanisation, industry, ratio of capital stock to labour, ratio of purchasing price index for fuels and power to price index for capital investment, ratio of exports to GDP, percentage of output by SOEs, interaction between FDI and human capital	Urbanisation significantly increases aggregate energy intensity (third greatest), electricity intensity (greatest impact) and coal intensity (second greatest).
(Ma, 2015)**	1986 – 2011	China	POLS, FE, FE-IV, MG, CCEMG, AMG	Dependent: energy intensity (electricity intensity, coal intensity). Explanatory: income, urbanisation, industrialisation	Urbanisation affects energy intensity in the long run: 0.14% to 0.37%. Urbanisation affects electricity intensity in the long run: 0.23% to 0.27%. Urbanisation doesn't affect (increase) coal intensity.

Author	Data set	Countries	Method (Model)	Variables	Relationship
(Azam *et al.*, 2015)	1980 – 2012	Indonesia, Malaysia, Thailand	Normality test, CSUSM model stability test, Park test for heteroscedasticity, ADF unit root test, Durbin Watson test, OLS	Dependent: energy consumption per capita. Explanatory: real growth, FDI, trade openness, population growth rate, urbanisation, HDI	Urbanisation has a significant impact on energy consumption for Thailand (0.63%) and Indonesia only.
(Li and Lin, 2015)	1971 – 2010	73 countries	STIRPAT, POLS, FE, RE, FE-GLS, FE-DK, FD, dynamic panel data (DPD)	Dependent: total energy use. Explanatory: population, GDP per capita, industrialisation, urbanisation, energy intensity, CO2 intensity per GDP, CO2 intensity per energy use.	Low-income countries: urbanisation decreases energy consumption. Middle/low-income countries: urbanisation significantly increases energy consumption. Middle/high-income countries: urbanisation doesn’t significantly affect energy consumption. High-income countries: urbanisation significantly increases energy consumption.
(Wang, Chen and Kubota, 2015)	1980 – 2009	ASEAN Countries	Multivariate causality framework, Breitung test, LLC test, IPS test, ADF, PP, FMOLS, VECM	Energy consumption, CO2 emissions, urbanisation	1% increase in urbanisation leads to 0.78% increase in energy use, and 0.2% increase in CO2 emissions. Urbanisation causes energy consumption in the short-run.
(Sodri and Garniwa, 2016)	2001 – 2014	Jakarta, Indonesia	ADF, Phillips-Peron, VECM	Dependent: road energy use, CO2 emissions. Explanatory: urbanisation.	Urbanisation Granger-causes road energy use
(Q. Wang *et al.*, 2016)**	1990 – 2012	China	Ridge regression	Dependent: energy consumption, CO2 emissions. Explanatory: population, GDP per capita, energy efficiency, urbanisation level, car ownership, proportion of non-agricultural industry, rural income, proportion of coal (for CO2 only).	Urbanisation leads to increases in energy consumption, but it’s not the only factor. The extent of the increase differs between provinces and depends on how urbanised the province already is.
(Rafiq, Salim and Nielsen, 2016)	1980 – 2010	22 Increasingly urbanised emerging economies	ADF, PP, cointegration test (Benerjee and Carrion-i-Silvestre), PMG Granger-causality test, robustness test	Dependent: CO2 emissions, energy intensity. Explanatory: population, GDP per capita, renewable energy, non-renewable energy, urbanisation, trade liberalisation	Population density increases energy intensity and CO2 emissions. Urbanisation significantly increases energy intensity but has no effect on CO2 emissions.
(Liu *et al.*, 2017)**	2006 – 2012	30 Provinces in China	STIRPAT, Spatial Durbin Panel Data Model (SDPDM)	Dependent: energy consumption. Explanatory: GDP, urbanisation rate, proportion of secondary industry, proportion of tertiary industry, share of coal in total energy consumption (structure of energy consumption), energy prices.	First model: 1% increase in urbanisation directly decreases energy consumption by 0.076%, indirectly increases energy consumption by 0.161%, with a total effect of an increase of 0.085%. Second model: 1% increase in

Author	Data set	Countries	Method (Model)	Variables	Relationship
					urbanisation causes 0.089% decrease in energy consumption.
(Elliott, Sun and Zhu, 2017)**	1995 – 2012	30 Provinces in China	Augmented Mean Group (AMG) estimator	Dependent: energy intensity. Explanatory: income per capita, industrialisation, urbanisation, subsector intensity.	1% increase in urbanisation leads to a 0.753% increase in electricity energy intensity and a 1.473% increase in coal energy intensity
(Shahbaz, Chaudhary and Ozturk, 2017)	1972 Q1 – 2011 Q4	Pakistan	STIRPAT, ARDL bounds, VECM Granger causality	Dependent: energy consumption per capita. Explanatory: urban population per capita, GDP per capita, industry and service sector value added (proxy for technology), number of cars and buses (proxy for transportation).	Urbanisation Granger-causes energy consumption. Urbanisation Granger-causes affluence, transportation and technology. Feedback effect between energy consumption and economic growth.
(Yang, Liu and Zhang, 2017)**	2000 – 2010	China	Pooled OLS, Fixed effects (FE), Random Effects (RE)	Dependent: GDP per capita. Explanatory: electricity consumption per capita, urbanisation rate, capital formation per capita.	Urbanisation leads to increases in energy consumption (for all urbanisation groups). Effect of urbanisation on economic growth is positive and significant for middle and high-income groups.
(Bilgili *et al.*, 2017)	1990 – 2014	10 Asian countries	AMG estimator, Dumitrescu-Hurlin panel causality test	Dependent: energy intensity. Explanatory: GDP per capita, urbanisation, ruralisation, export, renewable energy consumption, non-renewable energy consumption.	China and India: urbanisation negatively affects energy intensity in the long-run. Malaysia, Nepal, Philippines, South Korea, Thailand and Vietnam: urbanisation positively affects energy intensity. Indonesia and Bangladesh: no significant effect.
(Fan, Zhang and Wang, 2017)**	1996 – 2012	China	Divisia decomposition method	Urbanisation decomposition, income decomposition, energy source decomposition	Urbanisation contributed 15.4% of the increase in residential energy consumption for the period. Urbanisation decreases coal consumption, but increases oil, gas, heat and electricity consumption.
(Zhao and Zhang, 2018)**	1980 – 2010	China	Time series regression	Dependent: energy consumption. Explanatory: urbanisation, economic growth (GDP), industrialisation.	1% increase in urbanisation, 1.4% increase in energy consumption
(Bakirtas and Akpolat, 2018)	1971 – 2014	Colombia, India, Indonesia, Kenya, Malaysia, Mexico	Dumitrescu-Hurlin panel Granger causality test, bivariate and trivariate Granger causality analysis, LM test	Energy consumption per capita, GDP per capita, urbanisation.	Bivariate analysis: Granger causality from urbanisation to energy consumption (and economic growth). Trivariate analysis: Granger causality from urbanisation and energy consumption to energy consumption,

Author	Data set	Countries	Method (Model)	Variables	Relationship
					and from energy consumption and economic growth to urbanisation.

8.2 Appendix B – Supplementary material for Chapter 3

Statistical tests for Section 3.3.1.

Table 8.3 - Augmented Dickey-Fuller test for stationarity (null hypothesis: series is non-stationary).

Time series	Lag order	p-value	Outcome
Total energy consumption	2	< 0.001	No unit root. Stationary series.
Total electricity consumption	2	< 0.001	No unit root. Stationary series.

Table 8.4 - Hausmann test: Fixed effects vs Random effects (null hypothesis: preferred model is random effects).

Dependent variable	Model	p-value	Outcome
Total energy consumption	Fixed vs random	<< 0.001	Reject null hypothesis: use fixed effects.
Total electricity consumption	Fixed vs random	<< 0.001	Reject null hypothesis: use fixed effects.

Table 8.5 - Lagrange Multiplier test for time-fixed effects (null hypothesis: no time-fixed effects).

Dependent variable	Model	p-value	Outcome
Total energy consumption	Fixed effects	<< 0.001	Significant time-fixed effects.
Total electricity consumption	Fixed effects	<< 0.001	Significant time-fixed effects.

Table 8.6 - Breusch-Pagan test for the presence of heteroskedasticity (null hypothesis: homoskedasticity).

Dependent variable	Model	p-value	Outcome
Total energy consumption	Fixed effects	<< 0.001	Presence of heteroskedasticity.
Total electricity consumption	Fixed effects	<< 0.001	Presence of heteroskedasticity.

Table 8.7 - Results for test for serial correlation from estimating Equation 3.4 (null hypothesis: no serial correlation in idiosyncratic errors).

Dependent variable	Model	$\hat{\rho}$	Significance	Outcome
Total energy consumption	Fixed effects	0.939	<< 0.001	Serial correlation in idiosyncratic errors.
Total electricity consumption	Fixed effects	0.895	<< 0.001	Serial correlation in idiosyncratic errors.

Table 8.8 - Estimation results of the VAR model.

	Total energy consumption		Electricity consumption	
Country	VAR	GC	VAR	GC
Angola	0.071	TOTEN → UR	0.059	-
Benin	0.999 ***	UR → TOTEN	0.282 *	-
Botswana	0.321 ***	UR → TOTEN	0.042	-
Burkina Faso	0.352 ***	UR → TOTEN TOTEN → UR	0.176	ELEC → UR
Burundi	-0.005	TOTEN → UR	0.162 *	ELEC → UR UR → ELEC
Cameroon	0.160 *	UR → TOTEN TOTEN → UR	0.100	ELEC → UR
Cape Verde	0.453 ***	UR → TOTEN TOTEN → UR	0.208 *	-
CAF	0.824 ***	UR → TOTEN	0.389 **	UR → ELEC
Chad	0.204 *	UR → TOTEN	0.154	ELEC → UR
Comoros	0.112	TOTEN → UR	0.123	ELEC → UR
DR Congo	0.051	TOTEN → UR	0.210 *	UR → ELEC ELEC → UR
Congo, Rep	0.207 **	UR → TOTEN	0.084 *	UR → ELEC
Ivory Coast	0.154	-	0.315 **	UR → ELEC
Djibouti1	-0.340	TOTEN → UR	0.342	ELEC → UR
Eswatini	0.433 ***	UR → TOTEN TOTEN → UR	0.552 *	UR → ELEC
Equatorial Guinea	0.794 **	UR → TOTEN	0.431 **	UR → ELEC
Ethiopia2	0.110	TOTEN → UR	0.051	ELEC → UR
Gabon	0.171 **	UR → TOTEN	0.127	ELEC → UR
Gambia	0.152 **	UR → TOTEN	0.072	-
Ghana	0.331 ***	UR → TOTEN TOTEN → UR	0.239 **	UR → ELEC
Guinea	0.400 **	UR → TOTEN	0.005	ELEC → UR
Guinea Bissau	0.129	TOTEN → UR	0.009	ELEC → UR
Kenya	0.299 ***	UR → TOTEN	0.310 **	UR → ELEC
Lesotho3	0.786 **	UR → TOTEN	0.203	ELEC → UR
Madagascar	0.387 ***	UR → TOTEN	0.112	ELEC → UR
Malawi	0.370 ***	UR → TOTEN TOTEN → UR	0.563 ***	UR → ELEC ELEC → UR
Mali	0.420 **	UR → TOTEN	0.319 *	UR → ELEC ELEC → UR
Mauritania	0.209	TOTEN → UR	0.172	ELEC → UR
Mauritius	3.727 ***	UR → TOTEN TOTEN → UR	1.486 ***	UR → ELEC ELEC → UR
Mozambique	0.524 ***	UR → TOTEN TOTEN → EN	0.797 ***	UR → ELEC ELEC → UR
Namibia4	0.989 ***	UR → TOTEN	0.861 *	-
Niger	0.112	-	0.070	-
Nigeria	0.285 ***	UR → TOTEN	0.233 *	ELEC → UR
Rwanda	-0.025	-	0.038	ELEC → UR
Senegal	0.294 **	UR → TOTEN	0.557 **	UR → ELEC ELEC → UR
Seychelles	0.966 *	-	1.171 **	UR → ELEC
Sierra Leone	0.084	TOTEN → UR	-0.070	-
South Africa	0.202 **	UR → TOTEN	0.191 **	UR → ELEC
Sudan	0.075	-	0.014	-
Tanzania	0.105	TOTEN → UR	0.390 ***	UR → ELEC ELEC → UR
Togo	0.417 ***	UR → TOTEN	0.612 ***	UR → ELEC
Uganda	0.659 ***	UR → TOTEN	0.512 ***	UR → ELEC ELEC → UR
Zambia	0.102 ***		0.192 **	UR → ELEC ELEC → UR
Zimbabwe	0.001	TOTEN → UR	-0.002	-

VAR – coefficient of first lag of urban population on type of energy; GC – Granger causality: urbanisation Granger-causes type of energy

Significance codes: 0.01 '***', 0.05 '**', 0.1 '*'

1 Shorter time series 1985 – 2014, 2 Shorter time series 1981 – 2014, 3 Shorter time series 1990 – 2014, 4 Shorter time series 1990 – 2014

Table 8.9 - Estimation results of the variable coefficients model.

Country	Total energy consumption	Electricity consumption	Country	Total energy consumption	Electricity consumption
AGO	-2.32*	-4.64***	MOZ	-7.18	-19.71**
	(1.15)	(0.94)		(5.77)	(7.05)
BDI	5.11	2.49	MRT	-0.05	-1.32*
	(2.17)	(1.54)		(1.51)	(0.61)
BEN	-4.21*	-2.55**	MUS	9.04	4.33
	(2.23)	(1.09)		(2.87)	(2.51)
BFA	-2.87***	-0.71*	MWI	-0.13	0.55
	(0.58)	(0.37)		(0.49)	(0.37)
BWA	0.03	-0.63***	NAM	1.06	-7.37*
	(0.20)	(0.12)		(2.35)	(3.60)
CIV	6.04	3.31	NER	-0.26	-0.15
	(1.37)	(2.92)		(1.19)	(0.84)
CMR	0.24	-2.28*	NGA	0.33	4.36
	(1.01)	(1.05)		(1.91)	(1.87)
COD	-26.68***	-30.34***	RWA	-0.19	0.14
	(4.16)	(5.62)		(0.15)	(0.09)
COG	-2.16	0.77	SDN	-1.38**	-1.85***
	(2.10)	(1.35)		(0.52)	(0.42)
COM	-3.24***	-3.27***	SEN	-3.02	2.28
	(0.92)	(0.72)		(2.19)	(3.12)
CPV	-5.58***	0.28	SLE	-2.38	-3.08
	(1.04)	(0.24)		(3.22)	(4.99)
ETH	-0.44	1.80	SWZ	-4.98***	0.12
	(1.87)	(1.09)		(0.97)	(0.86)
GAB	-2.05*	0.96	SYC	-9.57*	8.17
	(1.03)	(0.63)		(4.15)	(1.34)
GHA	6.25	22.62	TCD	-2.40	2.53
	(8.49)	(12.16)		(2.28)	(0.95)
GIN	16.25	-14.57	TGO	0.50	4.57
	(9.23)	(14.03)		(7.26)	(5.83)
GMB	-3.53***	-2.66**	TZA	8.12	6.09
	(0.74)	(1.04)		(1.36)	(2.01)
GNB	2.28	2.08	UGA	-4.67***	3.42
	(0.29)	(0.47)		(0.78)	(2.10)
KEN	1.76	0.33	ZAF	-0.15	-1.54*
	(0.67)	(0.83)		(0.59)	(0.75)
LSO	4.99	2.21	ZMB	4.46	3.33
	(0.57)	(0.81)		(0.48)	(0.82)
MDG	-2.34	2.19	ZWE	3.33	3.83
	(2.10)	(1.30)		(1.24)	(0.89)
MLI	-5.03***	4.21			
	(1.31)	(1.87)			

***p < 0.001; **p < 0.01; *p < 0.05

8.3 Appendix C – Supplementary material for Chapter 5

Model robustness

To evaluate the performance of the model we use a set of metrics. The first, McFadden's pseudo R2, uses the null and residual deviance to measure the model's predictive power. It is calculated as follows

$$\log\left(\mathrm{L_p}\right) = \frac{\text{Null deviance}}{-2}$$

$$\log\left(\mathrm{L_{null}}\right) = \frac{\text{Residual deviance}}{-2}$$

$$\text{McFadden's pseudo } \mathrm{R}^2 = 1 - \frac{\log\left(\mathrm{L_p}\right)}{\log\left(\mathrm{L_{null}}\right)}$$

McFadden's pseudo R2 for all the models is reported in the regression tables.

Using a confusion matrix, we tabulate households actual access status vs their predicted status. The table below shows the confusion matrix for the model using types of habitats as the main explanatory variable.

		Predicted	
	Access	No	Yes
Actual	No	643	120
	Yes	296	513

Finally, for the two predicted models that include all the control variables, we plot a graph of the predicted probability of households having access to electricity along with their actual access status. Figure *8.1* shows that, for both models, households with access to electricity are predicted to have a high probability of having access to electricity and households without access to electricity are predicted to have a low probability of having access to electricity.

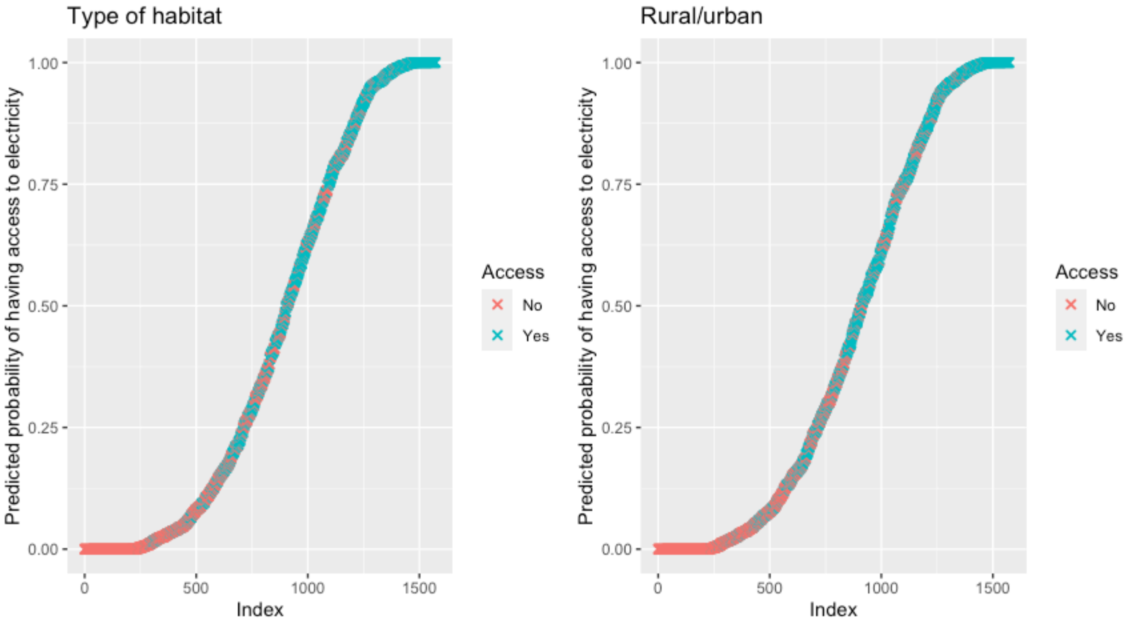

Figure 8.1 - Model prediction power: predicted probability of access to electricity vs actual electrification status of households.

Table 8.10 - Regression results of the first model showing the coefficients of the control variables.

	Dependent variable:						
	Access to electricity						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Household characteristics							
Monthly income			3.248***	3.190***	2.714***	2.647***	3.517***
			(0.205)	(0.284)	(0.298)	(0.298)	(0.349)
Household education			1.271***	1.239***	1.256***	1.253***	1.243***
			(0.036)	(0.049)	(0.050)	(0.050)	(0.052)
Number of households in the dwelling			1.831**	2.071**	2.035**	1.985**	1.718*
			(0.257)	(0.314)	(0.325)	(0.330)	(0.279)
Household members with bank account			2.299***	2.417***	2.685***	2.716***	2.949***
			(0.175)	(0.245)	(0.257)	(0.257)	(0.306)
Number of years in the community			0.986**	0.989	0.988	0.989	0.991
			(0.007)	(0.008)	(0.008)	(0.008)	(0.010)
Community characteristics							
Distance from city				0.979**	0.979**	0.979**	0.888***
				(0.009)	(0.009)	(0.009)	(0.032)
Community has a grid connection				6.512***	6.069***	6.180***	14.006***
				(0.406)	(0.394)	(0.398)	(0.947)
Number of years with grid connection				1.027**	1.019*	1.020*	1.081***
				(0.011)	(0.010)	(0.010)	(0.026)
Demographic and regional variables							
Population density of sector					4.080***	4.070***	
					(0.461)	(0.474)	
Kigali						1.854	
						(0.378)	
Locality		10.626***	6.030***	2.384***	2.097**	1.909**	1.671
		(0.259)	(0.245)	(0.286)	(0.291)	(0.310)	(0.591)
Type of habitat (reference category: Isolated rural)							
Umudugudu	3.127***	2.071***	1.457	2.636***	2.495***	2.492***	2.215**
	(0.241)	(0.247)	(0.246)	(0.241)	(0.256)	(0.258)	(0.360)
Unplanned rural	1.574	1.604	2.252***	2.397***	2.183**	2.178**	2.068*
	(0.288)	(0.297)	(0.277)	(0.326)	(0.322)	(0.323)	(0.386)
Unplanned urban	45.691***	8.289***	5.341***	3.956***	2.920***	2.325**	2.144*
	(0.322)	(0.332)	(0.333)	(0.356)	(0.371)	(0.345)	(0.445)
Old resettlement	1.844	1.760	2.873	2.414	2.127	2.009	3.049**
	(0.522)	(0.575)	(0.646)	(0.574)	(0.535)	(0.522)	(0.523)
Modern urban	29.144***	10.482***	4.809*	2.390	1.708	1.610	2.442
	(0.779)	(0.601)	(0.920)	(1.012)	(1.049)	(1.023)	(1.061)
Constant	0.105***	0.088***	0.0002***	0.0001***	0.00000***	0.00000***	0.0001***
	(0.206)	(0.223)	(0.833)	(1.244)	(1.591)	(1.604)	(2.172)
Sector fixed effects	No	No	No	No	No	No	Yes
Locality dummy	No	Yes	Yes	Yes	Yes	Yes	Yes
Household characteristics	No	No	Yes	Yes	Yes	Yes	Yes
Community characteristics	No	No	No	Yes	Yes	Yes	Yes
Population density	No	No	No	No	Yes	Yes	No
Kigali dummy	No	No	No	No	No	Yes	No
McFadden's pseudo R-squared	0.21	0.3	0.39	0.48	0.49	0.49	0.59
Observations	3,269	3,269	2,180	1,572	1,572	1,572	1,572

Note: *p<0.1; **p<0.05; ***p<0.01
Coefficients reported are odds ratios instead of log odds (standard errors and p-values are unchanged).

Table 8.11 - Regression results of the second model showing the coefficients of the control variables.

	Dependent variable:			
	Access to electricity			
	(1)	(2)	(3)	(4)
Household characteristics				
Monthly income		2.645***	2.557***	3.423***
		(0.305)	(0.301)	(0.345)
Household education		1.272***	1.268***	1.256***
		(0.051)	(0.050)	(0.053)
Number of households in the dwelling		2.074**	1.971**	1.613*
		(0.312)	(0.319)	(0.265)
Household members with bank account		2.383***	2.421***	2.803***
		(0.246)	(0.247)	(0.292)
Number of years in the community		0.985*	0.986*	0.989
		(0.008)	(0.008)	(0.010)
Community characteristics				
Distance from city		0.978**	0.979**	0.889***
		(0.009)	(0.009)	(0.033)
Community has a grid connection		6.173***	6.183***	19.445***
		(0.405)	(0.408)	(1.101)
Number of years with grid connection		1.013	1.014	1.083***
		(0.010)	(0.010)	(0.029)
Demographic and regional variables				
Population density of sector		5.673***	5.248***	
		(0.429)	(0.435)	
Kigali			2.132**	
			(0.372)	
Locality (reference category: rural)				
Urban	22.751***	2.736***	2.249***	1.185
	(0.245)	(0.262)	(0.266)	(0.652)
Constant	0.138***	0.00000***	0.00000***	0.0001***
	(0.115)	(1.684)	(1.683)	(2.310)
Sector fixed effects	No	No	No	No
Household characteristics	No	Yes	Yes	Yes
Community characteristics	No	Yes	Yes	Yes
Population density	No	Yes	Yes	No
Kigali dummy	No	No	Yes	No
McFadden's pseudo R-squared	0.26	0.47	0.48	0.59
Observations	3,295	1,588	1,588	1,588

Note: *p<0.1; **p<0.05; ***p<0.01
Coefficients reported are odds ratios instead of log odds (standard errors and p-values are unchanged).

The Rwanda Multi-Tier Framework (MTF) survey

The World Bank and the Energy Sector Management Assistance Program (ESMAP) launched a global effort to collect data on energy access using the Multi-Tier Framework (MTF) method. The MTF approach measures access to energy provided by any technology based on several attributes: capacity, availability, reliability, quality, affordability, formality and health and safety. Based on these attributes, and the data collected to measure them, the framework then defines six tiers of access, from Tier 0 (no access) to Tier 5 (full access). Households in higher tiers have better supply, higher capacity and better-quality electricity, households in lower tiers have reliability and affordability issues, and are more vulnerable to health and safety issues. Details of how tier levels are determined based on the aforementioned attributes are presented later in this Appendix.

The MTF survey includes two questionnaires: a household questionnaire and a community questionnaire. The questionnaires are very detailed, mainly to provide the necessary information needed to determine the tier level households. The household questionnaire is concerned with household characteristics, access to electricity and other energy services. The community questionnaire collects data on the different communities are the households are part of. Information on the community within which households live can highlight useful information about why and when electricity is provided.

Sampling strategy

This subsection is a condensed version of the MTF's sampling strategy document for Rwanda. The subsections that follow highlight the importance of the special considerations needed when using survey data and creating variables for use in the analysis.

The sampling strategy for the Multi-Tier Framework (MTF) uses the United Nations' practical guideline (United Nations, 2011) for guidance on certain aspects of the sampling strategy, mainly for sample size calculation and sample weight calculation. For calculating the sample weight calculations, the sampling strategy also employs ICF International's Demographic and Household Survey Sampling manual (ICF International, 2012).

The sample size for the MTF survey is chosen to ensure accurate estimates of the percentage of households at the national and local level that have access to electricity and modern cooking services.

Stratification

The stratification strategy sets the rules with which stratification is implemented. Once the sample size is decided on, the stratification strategy is established. Stratification divides the sample units (households) into homogenous groups called strata, from which households are separately chosen based on certain rules. This process is useful because it increases the representativeness of the sample. However, because of this process, when analysing the data sample weights must be used.

The rules of the stratification strategy are:

1. Equal split between urban and rural areas.
2. Only access to electricity is used in the stratification strategy (despite the survey being design to also study access to modern energy cooking solutions). Sampling weights are used to make the analysis of the data representative of the larger population. They reflect the actual levels of electricity access of the population.
3. The sample will split between households connected to the grid and households not connected to the grid. Sample weights are be used to compensate for oversampling.

Twelve households sampled from each PSE (village or urban block).

Sampling frame

The sampling frame uses the 2012 Rwanda Population and Housing Census. This census is the most recent and covers the entire country. The sampling frame is list of all the primary sampling units in the population being surveyed.

Allocation of strata

The MTF survey uses the following allocation rules:

- Province: this is the highest-level unit. The provinces are selected as follows:
    - All the states in the country are selected.
    - The distribution of households selected for the survey will be proportional to the actual distribution in urban and rural areas in the states. So, the total number of households allocated to each province will be the ratio of the province population to total population multiplied by the sample size for the survey.
- Village: this is the primary sampling unit (PSU). Villages are allocated using the following:
    - For each province, villages are divided into urban and rural villages.
    - From each village, 12 households are selected. Therefore, the number of villages allocated to each province is 1/12 of the total number of households allocated to the province.
    - Villages are then divided into two groups: electrified and non-electrified.
    - If a village is less than 3% electrified, it is considered not electrified. If a village is more than 3% electrified, it is considered electrified.

Table 8.12 - The number of villages and households in rural and urban areas in each province in the survey sample.

Rural			Urban		
Province	Villages	Households	Province	Villages	Households
Kigali City (3.1% of households)	5	60	Kigali City (49.5% of households)	70	840
Northern (17.8% of households)	25	300	Northern (9.3% of households)	10	120
Southern (26.9% of households)	35	420	Southern (13.2% of households)	15	180
Eastern (27.4% of households)	40	480	Eastern (10.7% of households)	15	180
Western (24.7% of households)	35	420	Western (17.3% of households)	25	300
Total	140 PSUs	1,680	Total	135 PSUs	1,620

Selection of sample units in strata

The samples for the different strata are selected as follows:

- Province: all provinces are included in the sample.
- Village: using the sampling frame mentioned above, villages are selected as follows:
    - Villages are selected so that the strata allocation strategy is satisfied: 50-50 distribution of electrified and non-electrified households; 12 households per village.
    - Lists of villages for each state are created: a list of electrified villages and a list of not electrified villages. Once the lists are created, the villages can then be selected randomly. There are three possible scenarios:
        - The province has villages with electricity and villages without electricity
        - All the villages in the province have access to electricity
        - No villages in the province have access to electricity
- Household: selecting households is the last step in the stratification strategy. The selection process depends on the province and village households are selected from. The selection process is as follows:

- The province has villages with electricity and villages without electricity (the number of villages selected is designed to ensure a 50-50 split between households with and without electricity):
  - From villages with electricity: 10 households with electricity, 2 households without electricity.
  - From villages without electricity: 12 households without electricity
- All the villages in the province have access to electricity:
  - From villages with electricity: 6 households with electricity, 6 households without electricity.
- No villages in the province have access to electricity:
  - From villages without electricity: 12 households without electricity
  - From villages with electricity (from another province): 12 households with electricity

- Household selection in practice: Once the number of households to be selected from electrified and non-electrified villages is determined (as mentioned above), households are selected randomly from each village:
  - If a list of households and their electrification status is available, the households are then selected randomly from this list.
  - If a list is not available, it would have to be created.
  - If a list is not created before the survey date, on the survey date:
    - Make a list of households and their electrification status
    - Give each household a serial number
    - Households are then selected randomly from the list of electrified households and the list of non-electrified households

Structure of the sample and sampling procedure

The sample of households chosen for the survey is a stratified sample. It was selected in two stages. The first stage: selection of 275 villages from the sampling frame. The second stage: selection of 12 households per village. The sampling frame is divided into strata within which households are homogenous. The stratification strategy (mentioned above in Section <>) separates villages into urban and rural, and electrified and non-electrified in each province. The urban and rural, and electrified and non-electrified villages in each province each form a stratum (the homogeneity here is that households in an urban, electrified stratum in Kigali City province are similar). As a result, 20 strata were created (see Section <> for how the Strata variable was created). Households are then chosen independently in each sampling stratum.

In the first stage, the 275 villages were selected using the probability proportional to size procedure for the entire country. In the second stage, in each village selected in the first stage, 12 households were selected from the list of households in that village. In total, 3,300 households were selected for the survey.

Table 8.13 - Distribution of villages and households based on electrification status.

	Urban				Rural				Nationwide	
Province	Electrified		Not electrified		Electrified		Not electrified			
	Villages	HHs	Villages	HHs	Villages	HHs	Villages	HHs	Villages	HHs
Kigali City	57	684	11	132	2	24	9	108	79	948
Southern	8	96	10	120	17	204	12	144	47	564
Western	11	132	7	84	13	156	17	204	48	576
Northern	5	60	2	24	12	144	9	108	28	336
Eastern	6	72	18	216	12	144	37	444	73	876
Total	87	1,044	48	576	56	672	84	1,008	275	3,300

Calculating sample weights

The survey collects data using a stratification strategy. In this strategy, sample units are chosen randomly only after clustering them into strata. To account for this clustering process, sample weights are used. Sample weights are inflation factors that consider the probability that a sample unit (household) will be chosen given the distribution of the population from which the sample is being taken. Using sample weights is important to ensure validity of statistical inference when analysing the data, to reduce bias and to keep sample distribution similar to that of the population.

The sample weights for the MTF survey are calculated as follows. First, the design weight is calculated. This is the inverse of the probability that a unit will be chosen in the sample at each stage of selection. Then, the sample weight is corrected for non-response. This is done to account for non-response. For example, high income, urban households, more educated individuals and men are less likely to respond to surveys than poor, rural households, less educated individuals and women. Then, once adjustments are made to account for non-response (and sometimes, non-coverage), exceptionally large sample weights that could potentially affect the variance of survey estimates are trimmed.

The sample weights for each household in the MTF survey are available in the dataset as the “sample_weight” variable.

Survey data analysis

To analyse survey data, special consideration must be made for the way the data was collected. Regular data analysis using statistical software (such as Stata or R) treats data as if it were collected using random sampling. Surveys rarely use random sampling, and as the Section <> makes clear, the MTF survey uses stratification as a sampling strategy. Therefore, the statistical software must be made aware of the sampling strategy in order to attribute the characteristics of the survey data to the difference between the sampling strategy and random sampling. This is important because the sampling design affects the calculation of point estimates and standard errors of the coefficients in the models.

In the case of the MTF survey, the sampling weight will affect the calculation of the point estimate. For example, without considering the sampling weight, and, therefore, assuming the data was obtained using simple random sampling, when running a model to try to estimate the effect of household income on electricity access the software will assume that access to electricity is a 50-50 split and could underestimate the effect of income. Similarly, if the clustering process that’s part of the stratification strategy is not considered, it’s likely that standard errors will be underestimated, which could lead to statistical significance when there isn’t any.

Survey data analysis, therefore, considers the primary sampling units (PSUs), the sampling weight of each household, the levels of stratification, and the number of strata.

Sample weights

The dataset of survey results gives the sample weight of each observation (household). A sample weight is the reverse of the overall selection probability of each household. The sample weights are calculated based on the sampling strategy: two-stage, stratified cluster sampling. Separate sampling probabilities are calculated for each sampling stage. For the first stage, the probability of selecting the ith PSU in stratum j is calculated. For the second stage, the probability of selecting the household in the ith PSU is calculated. The final sample weight for each observation is the product of these two probabilities. The distribution of sampling weights is shown in Figure X below.

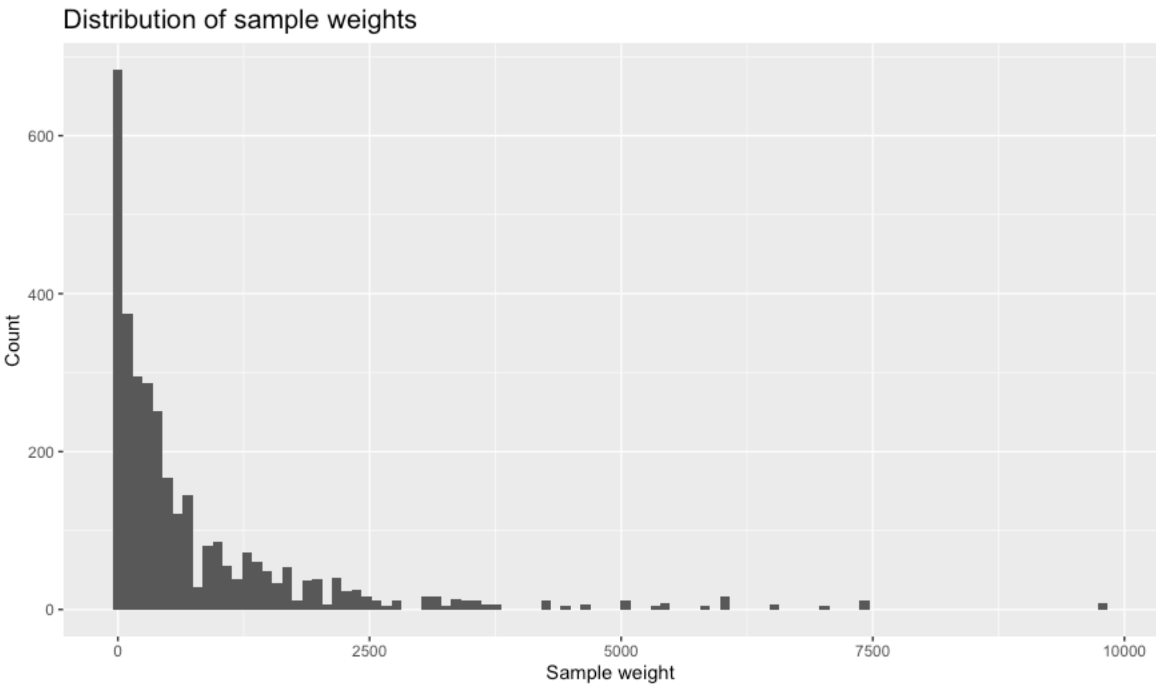

Figure 8.2 - Distribution of sample weights.

Table 8.14 - Population approximation using the sample weights and actual population from the 2012 Rwanda Population and Housing Census.

Province	Population (survey)	Population (RPHC)
Kigali	1,204,145	1,146,184
Eastern	2,295,389	2,590,051
Northern	2,043,226	1,686,788
Southern	2,543,396	2,544,201
Western	2,313750	2,426,318
Total	10,399,906	10,393,542

The questionnaires

The survey questionnaires are designed to help determine the level of energy access of households beyond the binary measure of having a grid connection.

Household questionnaire

The household questionnaire has 20 sections, labelled A to T. The sections are shown in Table *8.15*.

Table 8.15 - Sections in the household questionnaire.

Section	Description
A	Household roster
B	Household characteristics
C	Supply of electricity
D	Willingness to pay for a grid connection
E	Willingness to pay for solar device
F	Kerosene/fuel based/candle lighting
G	Dry-cell batteries
H	Household fuel consumption
I	Use of cooking solutions
J	Space and water heating
K	Willingness to pay for an improved cookstove
L	Household assets: transportation and agricultural equipment ownership and total
M	Household land ownership
N	Household economic shocks
O	Street lighting
P	Time use
Q	Health impacts
R	Attitudes
S	Women’s empowerment
T	Household based business/enterprise

Community questionnaire

The community questionnaire has 15 sections, labelled A to O. The sections are shown in Table *8.16*.

Table 8.16 - Sections in the community questionnaire.

Section	Description
A	Community identification
B	Community leaders
C	Background
D	Transportation, communication and water supply
E	Infrastructure and services
F	Community based organisations (CBO)
G	Non-governmental organisations (NGO)
H	Community businesses
I	Development projects
J	Shocks and natural disasters in last 12 months
K	Energy/fuel price in the community
L	Supply of electricity
M	Cooking
N	Street lighting
O	Attitudes

Creating the Tier variable

The MTF classification approach determines electricity access using seven attributes: capacity, availability, reliability, quality, affordability, formality, and health and safety. The classification then defines six levels of access: Tier 0 (no access) to Tier 5 (full access) (Table <>). Based on these attributes, each household is then assigned a tier.

To determine the tier for each household, the following steps were taken:

- For the capacity attribute, the daily Wh electricity consumption is used:
    - Survey question C22: "In the last month, how much electricity did your household use?" (in kWh).
    - Daily Wh electricity consumed: C22*1,000/30
    - The tier for each household is determined based on their daily Wh consumption as follows:
        - Tier 0: less than 12Wh
        - Tier 1: more than or equal to 12 Wh and less than 200 Wh
        - Tier 2: more than or equal to 200 Wh and less than 1 kWh
        - Tier 3: more than or equal to 1 kWh and less than 3.4 kWh
        - Tier 4: more than or equal to 3.4 kWh and less than 8.2 kWh
        - Tier 5: more than or equal to 8.2 kWh
- For the availability attribute, both daily and evening availability of electricity are used:
    - Daily availability:
        - Survey question C26B: "How many hours of electricity are available each day and night from the grid, in a typical month?" (in hours).
        - The tier for each household is determined based on the number of hours of electricity available each day:
            - Tier 0: less than 4 hours of electricity
            - Tier 2: more than or equal to 4 hours and less than 8 hours

        - Tier 3: more than or equal to 8 hours and less than 16 hours
        - Tier 4: more than or equal to 16 hours and less than 23 hours
        - Tier 5: more than or equal to 23 hours
  - Evening availability:
    - Survey question C27B: “How many hours of electricity are available each evening, from 6 pm to 10 pm from the grid, in a typical month?” (in hours)
    - The tier for each household is determined based on the number of hours of electricity available each evening:
        - Tier 0: less than 1 hour of electricity
        - Tier 1: more than or equal to 1 hour and less than 2 hours
        - Tier 2: more than or equal to 2 hours and less than 3 hours
        - Tier 3: more than or equal to 3 hours and less than 4 hours
        - Tier 5: more than or equal to 4 hours

- For the reliability attribute, the number of outages/blackouts that a household experiences in a week is used:
  - Survey question C29B: “In a typica day, how many outages/blackouts of the grid happen, in a typical month?” (number of blackouts)
  - Number of outages/blackouts per week: C29B*7
  - The tier for each household is determined based on the number of outages/blackouts per week:
    - Tier 2: more than 14 outages/blackouts/disruptions per week
    - Tier 3: equal to 14 outages/blackouts/disruptions per week
    - Tier 4: more than 3 and less than 14 outages/blackouts/disruptions per week
    - Tier 5: less than or equal to 3 outages/blackouts/disruptions per week

- For the quality attribute, damage to electrical appliances in the household is used:
    - Survey question C39: “In the last 12 months, did any of your appliances get damaged because the voltage was going up and down from the grid?”
    - Damage to household appliances: C39 (Yes, No)
    - The tier for each household is determined based on whether household appliances get damaged due to voltage fluctuations:
        - Tier 3: household experiences voltage problems that damages appliances
        - Tier 5: voltage problems do not affect the use of desired appliances
- For the affordability attribute, the cost of a standard annual consumption package of 365 kWh as a percentage of household income is used:
    - Survey questions:
        - C21: “In the last month, how much did you spend on the electric bill?” (in local currency)
        - C22: “In the last month, how much electricity did your household use?” (in kWh)
        - A20: “Please indicate the monthly income for this activity” (in local currency)
    - Cost of standard annual consumption package of 365 kWh as a percent of total income: (((C21/C22)*365)/ (household average for A20*12))*100 (%)
    - The tier for each household is determined based on what percent a standard annual consumption package constitutes of household income:
        - Tier 2: cost of standard annual consumption package of 365 kWh is more than 5% of household income
        - Tier 5: cost of standard annual consumption package of 365 kWh is less than 5% of household income
- For the formality attribute, the billing method for electricity is used:
    - Survey question C17: “How are you billed for electricity?”

    - Billing method: C17 (various billing methods or no billing for electricity)
    - The tier for each household is determined based on whether the household is billed for electricity (all methods of billing) or not:
        - Tier 3: no bill payments made for the use of electricity
        - Tier 5: bill is paid to utility, prepaid card seller or authorised representative
- For the health and safety attribute, physical damage from electrocution is used:
    - Survey question C41: “In the last 12 months, did any household members die or have permanent limb (bodily injury) damage because of the grid electricity?”
    - Harm from electrocution: C41 (Yes, No)
    - The tier for each household is determined based on whether members of the household have had any accidents with electricity:
        - Tier 3: serious or fatal accidents due to electricity connection
        - Tier 5: no past accidents due to electricity

Table 8.17 - MTF attributes of electricity access (adapted from..).

Attributes		Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Capacity	Power capacity ratings (W or daily Wh)	Less than 3 W	At least 3 W	At least 50 W	At least 200 W	At least 80 W	At least 2 kW
		Less than 12 Wh	At least 12 Wh	At least 200 Wh	At least 1 kWh	At least 3.4 kWh	At least 8.2 kWh
	Services		Lighting of 1,000 lmhr per day	Electrical lighting, air circulation, television and phone charging are possible			
Availability	Daily Availability	Less than 4 hours	At least 4 hours		At least 8 hours	At least 16 hours	At least 23 hours
	Evening Availability	Less than 1 hour	At least 1 hour	At least 2 hours	At least 3 hours	At least 4 hours	
Reliability		More than 14 disruptions per week			At most 14 disruptions per week or At most 3 disruptions per week with total duration of more than 2 hours	> 3 to 14 disruptions per week or ≤ 3 disruptions per week with > 2 hours of outage	At most 3 disruptions per week with total duration of less that 2 hours
Quality		Household experiences voltage problems that damage appliances				Voltage problems do not affect the use of desired appliances	
Affordability		Cost of a standard consumption package of 365 kWh per year is more than 5% of household income			Cost of a standard consumption package of 365 kWh per year is less than 5% of household income		
Formality		No bill payments made for the use of electricity				Bill is paid to the utility, prepaid card seller, or authorised representative	
Health and Safety		Serious or fatal accidents due to electricity connection				Absence of past accidents	

Table 8.18 - Survey questions and calculation process for the Tier levels of households.

Attributes		Question no.	Question	Calculation/process
Capacity	Power capacity ratings (daily Wh)	C22	In the last month, how much electricity did your household use? (in kWh)	(C22*1000)/30 (Wh)
Availability	Daily availability	C26 B	How many hours of electricity are available each evening, from 6 pm to 10 pm from the grid? (hours) B: In a typical month.	C26B (hours)
	Evening availability	C27 B	How many hours of electricity are available each evening, from 6 pm to 10 pm from the grid? (hours) B: In a typical month.	C27B (hours)
Reliability		C29 B	In a typical day, how many outages/blackouts of the grid happen? B: In a typical month.	C29B*7 (number of outages/blackouts)
Quality		C39	In the last 12 months, did any of your appliances get damaged because the voltage was going up and down from the grid?	C39 (number of appliances)
Affordability		C21	In the last month, how much did you spend on the electric bill? (local currency)	(((C21/C22)*365)/ (household average for A20*12))*100 (%)
		C22	In the last month, how much electricity did your household use? (in kWh	
		A20	Please indicate the monthly income for this activity. (local currency)	
Formality		C17	How are you billed for electricity?	C17 (types of billing) Coding: 1 if billed for electricity, 0 if not billed for electricity
Health and safety		C41	In the last 12 months, did any household members die or have permanent limb (bodily injury) damages because of the grid electricity?	C41 Coding: 1 if Yes, 0 if No

Creating the Strata variable

The MTF survey uses the most recent and comprehensive 2012 Rwanda Population and Housing Census as the sampling frame. Stratification was then carried out for the sake of geographical representation. The sample for the survey was selected in two stages. In the first stage of stratification, villages were selected based on “the probability proportional to size selection procedure” for the country. In the second stage, households were selected randomly from a list of residential households in the villages. A total of 275 villages were selected and 12 households per village.

The sampling frame was then divided into strata. Within each stratum, households are homogenous. The stratification process is used to ensure that the sample is efficient and representative of the larger population. The sample stratification was achieved by creating strata based on two criteria in each province: urban and rural villages, electrified and non-electrified villages. There are 5 provinces in Rwanda, and, hence, 20 strata were created, from which samples were selected independently.

The survey uses stratified sampling. Stratification is s sampling method that breaks up the population being surveyed into different groups, usually by certain characteristics such as gender. In this survey, villages are stratified by urban and rural first, then electrified and not electrified.

The survey dataset does not give a strata variable. There is a variable called "strata" in the dataset, but it doesn't represent the 20 strata created by the stratification strategy. To calculate the strata variable, the following steps were taken:

- The province code from the survey codebook was used. Each of the five provinces was assigned a code from 1 to 5.
- Then, whether a household is in an urban or rural area was determined by the locality variable from the household survey. The variable is coded as follows: 1 if the household is an urban village, 0 if the household is in rural village.
- To determine whether the villages from which each household was chosen were electrified or not, a couple of steps were taken:
    - The survey dataset has a variable called "strata". The variable has 469 unique values.
    - The "strata" variable in the dataset is a combination of the "Cluster" variable and the variable "C2" (whether the household has access to electricity or not). The "Cluster" variable ranges from 1 to 275, representing all 275 villages (PSU's). The "C2" variable is 1 when the household has access to electricity and 2 when the household doesn't. For example, if a household is in cluster 17 and has access to electricity, the household's strata variable would be 171; similarly, if a household is in cluster 137 and doesn't have access

to electricity, the household's strata variable is 1370. Table *8.19* below shows a random sample of household's and their respective strata variables.

- The "strata" variable, therefore, does not represent the 20 strata created by the stratification strategy. Splitting the "strata" variable up and taking the last digit to indicate whether a household has access to electricity or not is the same as just using the "C2" variable. So, the C2 variable is used as an indicator for whether a household has access to grid electricity or not.
- The stratification strategy groups villages into urban and rural, and electrified and not electrified. If a village has less than 3% electrification rate it's considered not electrified, if a village has more than 3% electrification rate it is considered electrified. Then, stratification employs the following hypothetical strategy was used to select villages and households in the strata (special cases not included):
  - A province has both villages with electricity and villages without electricity:
    - Chosen villages: 3 with electricity, 2 without electricity
    - For villages with electricity: 10 households with electricity, 2 households without electricity
    - For villages without electricity: 12 households without electricity
  - All villages in the province have access to electricity:
    - Chosen villages: 5 villages with electricity
    - Chosen households: 6 households with electricity, 6 households without electricity
  - No village in the state has access to electricity:
    - Chosen villages: 5 villages without electricity
    - Chosen households: 12 households without electricity
    - To ensure 50-50 split between electrified and non-electrified households in the sample, states with no

electrified villages and all 12 non-electrified households are chosen per village, are paired up with states where all villages are electrified, where 12 electrified households are chosen from each village.

- The survey dataset does not include a variable for whether a village is electrified or not. Based on the household selection strategy above, the following process was used to identify villages as electrified or not:
  - Each household has a C2 variable indicating whether it has access to grid electricity (1) or not (0).
  - Each cluster (village or PSU) has 12 households.
  - An "elecornot" variable is created and is coded as follows: 1 if the village is electrified, 0 if the village is not electrified.
  - For each group of 12 households in the same cluster (village or PSU), the number of households with access to electricity is counted:
    - If a cluster has more than 6 households with access to electricity, it is considered electrified ("elecornot" = 1). Each household in that cluster also has an "elecornot" = 1.
    - If a cluster has 6 or less households with access to electricity, it is considered not electrified ("elecornot" = 0). Each household in that cluster also has an "elecornot" = 0.

- The strata variable is created by combining the following variables into one three-digit variable:
  - Province code: 1 to 5
  - Locality (urban or rural): 1 if urban, 0 if rural
  - Electrified or not (elecornot): 1 if electrified, 0 if not electrified
- Table *8.20* below lists the strata code for the 20 strata.
- This method for creating the "electrified or not" variable, which determines whether villages are considered electrified or not by the stratification strategy, is in line with the sample allocations in the sampling strategy:

- The number of electrified and not electrified villages is calculated by dividing the number of households with “elecornot” equal to 1 and 0, respectively, by 12 (the number of households in each village/cluster).
- Number of electrified villages using the “electrified or not” variable: 143; number of electrified villages in the sample allocation: 143.
- Number of not electrified villages using the “electrified or not” variable: 131.6 (the fraction is due to the actual survey having 3,295 households instead of 3,300 from the sample design); number of not electrified villages in the sample allocation: 132.

Table 8.19 - Random sample of households and their respective strata variables from the survey dataset.

Household ID	Cluster	Access to electricity (1 = Yes, 2 = No)	Strata variable
1102020811009	1	Yes	11
1306010213130	67	Yes	671
2204020922015	93	No	932
2414020124066	103	No	1032
5309040853056	238	Yes	2381

Table 8.20 - The strata codes created for the survey data.

Province	Province code	Locality (1 if urban, 0 if rural)	Electrified or not (1 if electrified, 0 if not)	Strata code
Kigali City	1	0	0	100
Kigali City	1	0	1	101
Kigali City	1	1	0	110
Kigali City	1	1	1	111
Southern	2	0	0	200
Southern	2	0	1	201
Southern	2	1	0	210
Southern	2	1	1	211
Western	3	0	0	300
Western	3	0	1	301
Western	3	1	0	310
Western	3	1	1	311
Northern	4	0	0	400
Northern	4	0	1	401
Northern	4	1	0	410
Northern	4	1	1	411
Eastern	5	0	0	500
Eastern	5	0	1	501
Eastern	5	1	0	510
Eastern	5	1	1	511

Data manipulation

The household questionnaire is designed to gather information about the household as well as information about individual members of the household, such as level of education and monthly income. Sections A, parts of C, F, G, H, I, L and P all have datasets separate from the main dataset

The data for sections A and L must be manipulated for each household to have one datapoint for the variable being measured. Section A is the Household Roster, it includes questions on education, age, marital status, and employment. Section L is on household assets and asks questions about ownership of transportation and agricultural equipment.

Consequently, some of the variables had to be manipulated for use in the data analysis.

Average household income

The household questionnaire includes a Household Roster (Section A). The roster documents details about each member of the household. Question A.16 asks about each household member's main occupation over the past year. Question A.20 asks, "Please indicate the monthly income for this activity." The Average Household Income variable was created by taking the average monthly income as documented in Question A.20 of all members of the household that have an occupation. For rural households, which make up most of the Rwandan population, using an average household income would give similar results to using total household income because an electricity connection be considered a luxury purchase: it can only be accommodated once the basic needs of all household members have been satisfied.

Average years of education

Question A.9 in the household roster is a multiple-choice question about education. It asks, "What is the highest educational qualification acquired by each household member?" The response to the question is coded to show the highest educational qualification of the respondent from a list of seven levels of education, each corresponding to a number. The responses, from Primary Education to PhD, each correspond to a number from 1 to 7. The response is recorded for all members of the household. For example, in one household, the male head of household completed senior secondary education (Secondary A level), his wife completed junior secondary education (Secondary O level), of his three sons, two completed primary education and one completed senior secondary education, and his daughter completed primary education. This is useful information, but the analysis in this chapter uses the household as the unit of assessment. Two new variables were created with one datapoint each per household. The first variable, average years of education, was created by first converting the highest educational qualification of each household member to number of years of education. Rwanda uses a 6-3-3-4 system (Nuffic, 2015), Technical and Vocational Education and Training (TVET) is on average 1 year (K and Odette, 2017), and Masters and PhD degrees are 1 and 3 years, respectively (Nuffic, 2015). Second, the sum of the number of years of education of the members of the household was divided by the number of household members to give the average years of education. The second variable is the number of years of education of the head of the household.

Whether the community is electrified

To determine whether the community is electrified the analysis uses the variable created in process of creating the Strata variable of whether each village is electrified or not. The community questionnaire includes a section on Supply of Electricity (Section L). In this section, Question L.2 asks, “Is this community connected to the national grid or a mini-grid?” The response is coded as 1, 2 or 3, which signify if the community is connected to the national grid, mini-grid or not connected, respectively. This variable could potentially serve the same purpose but not all communities were surveyed.