Electricity Sector Reforms in Sub-Saharan Africa

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Electricity Sector Reforms in Sub-Saharan Africa

A Thesis Submitted by

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ABSTRACT

Electricity sector reforms has been one of the most transformative energy sector policies in sub-Saharan Africa (SSA) in modern history. However, studies on reforms in SSA remain limited, with quantitative analysis almost non-existent. This thesis contributes to the literature on electricity sector reforms in SSA through an assessment of reform performance and its connection to key electricity sector topics in the region including investments and productive efficiency, access, and cost efficiency. The thesis is structured in a three-paper format, with each paper focused on each of the key challenges mentioned.

In Paper One, I assess the performance of electricity sector reforms in 37 SSA countries between 2000 and 2017 using a parametric multi-input multi-output distance function and a Stochastic Frontier Analysis (SFA) approach. From this assessment, I found an effective reform model in SSA to involve vertical unbundling with an electricity law, a sector regulator, and private ownership and management of electricity assets where desirable. I also found reforms to be positively correlated with efficient investments in generation but negatively correlated with reduction in technical network losses. On the institutional front, perceptions about non-violent institutional features such as corruption and governance effectiveness were found to have no significant relationship with reform performance whereas negative perceptions about terrorism and violence were found to be negatively correlated with reform performance.

In the Second Paper, I examined the determinants of electricity access performance in 46 SSA countries from the viewpoint of reforms using a production function and SFA from 2000 to 2017. I found generation capacity adequacy and the efficiency with which electricity is produced and used to be positively correlated with the rate of access expansion. The wealth of countries was also found to be positively correlated with improved electrification outcomes while the wealth of households in a country was found to be negatively correlated with inefficiencies that interfere with electrification efforts. The reform step that was found to engender these positive electrification outcomes was the presence of a sector regulator, while unbundling and private sector participation were found to be negatively correlated with access performance.

In the Third Paper, I explored the relationship between reforms and cost of electricity services to provide an economic perspective to issues of cost under-recovery in SSA electricity systems. Through a synthesis of reform theories and case studies and using small electricity systems as a surrogate for liberalised electricity systems without competitive markets, I showed the connection between reforms and costs. I made a case for a structural approach to issues of cost under-recoverability in SSA electricity systems leveraging contestability opportunities in mobile powerplants in generation, yardstick competition in distribution and retail and regional integration of electricity markets.

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Dedication

To mum and dad

Declaration

None of the material contained in this thesis has been submitted for a degree in any other university. The results contained in some of the chapters are based on joint research articles with my first set of supervisors Professor Tooraj Jamasb and Doctor Manuel Llorca and under the guidance of my second set of supervisors Dr Thomas Renström and Dr Laura Marsiliani during the completion of this thesis . Where the material is drawn from this joint work, proper references have been made. This thesis was funded by the Ghana Education Trust Fund (Getfund).

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My eternal gratitude to my parents for always encouraging me to dream and giving the tools I needed to manifest my dreams. I thank my brothers and sister for their continued presence, unwavering support and being my closest friends. I thank my husband, Mike LaSorda, for his soothing love and steadfast support. Finally, to my friends Xiaoxiao , Nazha, Israa, Tevy, Doa’a, Adila, Juinn, and Jacqueline, for giving me a great support system during my time in Durham. You will always be an important part of my life.

1. Introduction

1.1. Background

In the early 1970s, a series of economic and geopolitical events destabilized the global economy. It began with the collapse of the Bretton Woods system in 1971 when the US suspended convertibility of the dollar into gold, creating a lot of uncertainties in global financial markets as countries experimented with various exchange rate models (Bordo and Eichengreen, 1993; United Nations, 2017). Around this period, in 1973, the Arab members of the Organisation of Petroleum Exporting Countries (OPEC) imposed a crude oil supply embargo on the US (and subsequently Netherlands, Portugal, and South Africa). This led to a sharp increase in oil prices and a cost-push inflation as production costs skyrocketed (United Nations, 2017). The combination of high inflation rates and the prolonged uncertainty after the collapse of the Bretton Woods system led to a stock market crash in 1973-1974 which initiated a global economic recession.

This recession was different, as it was marked by a novel phenomenon of stagnant demand and unemployment but high inflation rates, what came to be dubbed “stagflation” (Grubb et al., 1982)[1]. With no prior experience with stagflation, countries (especially the developed ones) responded to the crises with an immoderate combination of monetary and fiscal policies which restricted credit and curtailed government spending (United Nations, 2017). These anti-inflationary policies did not only constrain access to capital at the national levels but also at the international level. For developing countries, these developments meant a higher cost of borrowing, restricted access to foreign concessional assistance and lower exports due to reduced global demand. By the early 1980s, several of these countries were in Balance-of-Payment difficulties, which was exacerbated by poor domestic policies and fiscal irresponsibility following the oil price shocks (Canak and Steidlmeier, 1989).

Mexico was the first to announce in 1982 that it could not continue its debt servicing without new loans or rescheduling (Canak and Steidlmeier, 1989). This inspired a succession of sovereign defaults around the world, with one country after another declaring a similar inability to repay (Canak and Steidlmeier, 1989; Bradshaw and Huang, 1991). This unilateral insolvency threat by these highly indebted countries, concentrated in Latin America and sub-Saharan Africa (SSA), threatened the stability of global capital markets and leading international finance institutions (Canak and Steidlmeier, 1989). Thus, these establishments launched a concerted effort through multilateral organisations to recover outstanding loans (Bradshaw and Huang, 1991).

The World Bank and the International Monetary Fund (IMF) led these efforts, and they did so with a simple but clear message, that they were only open to debt renegotiation and restructuring if countries agreed to Structural Adjustment Programmes (SAPs) to address the systemic issues in their economies

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[1] Low economic growth and weak demand is often associated with deflation. The concept of cost-push inflation was new.

(United Nations, 2017). The SAPs involved a set of reforms anchored in neoclassical ideas of market fundamentalism which had gained widespread popularity at the time, following the failure of neo-Keynesian models of growth in explaining and addressing stagflation.[2] These neoliberal growth models advocated for the elimination of price controls, the deregulation of markets, the removal of entry barriers and the reduction of state influence in economies, typically through austerity measures and privatization. Thus, the goal of the SAPs was to propel industries with monopoly market structures towards the market ideal of more competition (United Nations, 2017).

In the utilities sector, these principles were first applied in the telecommunication industry following a high-profile antitrust suit by the US Department of Justice (DoJ) against the American Telephone & Telegraph (AT&T) company in 1974 (US DoJ, 1974). The suit questioned whether effective regulation of the networks could coexist with conditions for effective and undistorted competition in other parts of the industry, or whether a structural separation between these two activities was necessary (Armstrong et al., 1994). The latter was chosen, and AT&T was divested in what is considered one of the earliest utilities reforms worldwide.

Given the striking similarities amongst network industries (despite some differences in economic characteristics), the case of AT&T spurred global interest in how other infrastructure utilities like electricity, water, gas, and railways were structured and managed. In the electricity sector, these principles were first applied in the US, UK, Argentina, Chile, and Norway. In these countries, the perverse outcomes of monopoly power and Rate of Return (RoR) regulation in electricity sectors were being observed in the forms of excess generation capacity, expensive technology choices, and inefficient production (Sen et al., 2018; Pollitt, 2009). Thus, electricity sectors in these contexts were reformed with the goal of incentivising cost control by shifting the risks of technology choices, construction costs and operational mistakes from consumers to suppliers (Joskow, 2005; Pollitt, 2009; Armstrong et al., 1994).

The reforms involved the introduction of policies, regulations, and institutions that would unfetter the monopoly of state-owned utilities and provide avenues for private actors to participate in competitive

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[2] Keynesian models of growth were unable to explain the sharp changes in real GDP and price levels (stagflation) at the time. It had become apparent that monetary policy and aggregate supply, both in the long and short run, had important roles to play in economic policy. This gave rise the neo-classical growth models which discredited the effectiveness of fiscal policy in shifting aggregate demand curves. They argued that when households observe government policies that increase debt, they reduce consumption in anticipation that they, or their progeny will have to pay for this debt in the future, subsequently cancelling any tendency for an expansionary policy to affect aggregate demand. Thus, an effective and sustainable model of growth will be one that allow the free operation of markets without government intervention.

markets (World Bank, 1993, 2004; Jamasb et al., 2014; Jamasb et al., 2017). The rationale was that unbundling of the traditional vertically integrated utility would disentangle the vertical diseconomies in the Electricity Supply Industry (ESI). Then, liberalization of the potentially competitive segments (generation and retailing) would facilitate new entrants from the private sector, which would generate and sustain competition to reveal optimal levels, mix and prices (Joskow and Schmalensee, 1985; Ennis and Pinto, 2002; Toba, 2007; Jamasb et al., 2006). On the other hand, regulation of the networks (i.e., transmission and distribution), and sometimes ownership change would provide high-powered incentives and hard budget constraints. This would internalize the problem of information asymmetry and eradicate the perverse incentives associated with natural monopolies while improving governance and fighting corruption (Galal et al., 1994; Domah and Pollitt, 2005; Pollitt, 2012). These efficiency improvements are then expected to be passed on to consumers, directly through price and quality competition or indirectly through re-investment in new assets (Sen and Jamasb, 2012).

In the ensuing years, reforms proved successful in these pioneer reforming countries, with observed downward price trends, high switching rates in retail suppliers (indicating increased competition) and a reduction in the cost of regulation per unit of energy delivered (Pollitt, 2009). With these successes, the reform approach used in these countries became the blueprint for electricity sector reforms worldwide, and the standard prescription by the SAPs for reforming electricity sectors.

This prescriptive approach to reforms by the SAPs was met with strong criticisms. The "standard reform model" that was being prescribed was censured for being narrow in its objectives, restrictive in terms of the instruments it deployed and limited in its vision of the development process (United Nations, 2017). It was argued that although the rationale for reforms was similar across countries, the contexts were remarkably different. Contrary to the conditions of excess capacity in pioneer reforming countries, there was a chronic shortage of capacity in the developing countries that partook in the SAPs (Bergara et al., 1997; Kessides, 2012). In addition, electricity supply was unreliable, access rates were low, and utilities were financially unviable. Consequently, effective reforms in these contexts should facilitate investments, improve the operational performance of sector utilities, eradicate subsidies, accelerate access to electricity services, and improve the quality of electricity supply (Pollitt, 2009). Thus, the puzzle was whether reforms would be as effective in addressing shortages as it had been in wiping excesses, and at what cost.

This promised to be particularly challenging given that in most developing countries, there were problems of weak and often non-existent regulatory institutions, political opposition to the economic pricing of electricity, and the unattractiveness of revenues in local and often weak currencies (Pollitt, 2009). In addition, austere reform measures such as the removal of subsidies and the privatisation of utilities were politically unpopular, with the tendency to adversely impact the poorest and most vulnerable groups. Subsequently, reforms were widely criticised to be in the rent-seeking interests of private capital over considerations of social welfare (Joskow, 1998a, 1998b). In fact, the entire SAPs were reviled as an effort to create an outlet of profitable investments for the inevitable excessive capital accumulation of capitalist markets in developed economies (Piketty and Goldhammer, 2020). Subsequently, reforms were met with strong resistance in many countries, especially in those with strong socialist orientation.

These sentiments, however, did not dissuade the requirement of reforms by countries seeking financial support from International Development Organizations. Rather, it was agreed that while the standard reform model was not the perfect fit for the electricity sectors of most developing countries, it still embodied relevant elements for these contexts. Thus, reforming countries were encouraged to review and select the options, mechanisms, and pace of reforms that were most appropriate for their needs and circumstances, but with the goal of fully deregulating their electricity sectors in the long run (World Bank, 1993, 2004; Haselip and Potter, 2009). Subsequently, reforms became one of the largest energy policy experiments in the developing world, leading to the proliferation of reform models across the region.

1.2. Motivation of Research

SSA[3] was one of the largest participating regions in the SAPs, with about 37 of its 48 countries having initiated reforms as of 2017. In SSA, countries adopted a phased approach to reforms, with the first phase focused on liberalizing the sector to facilitate investments while improving technical and operational efficiency. This was complemented with specialized programs that were run in parallel to address social issues such as access and affordability (Carvalho et al., 2015). Once issues of inadequate capacity had been addressed, price-cost margins closed, and operational efficiency improved, reforms

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[3] Sub-Saharan Africa (SSA) is geographically the area of the continent of Africa that lies south of the Sahara. It comprises 48 countries of which 23 are Low-Income,[3] 19 are Lower-Middle-Income,[3] and 6 are Upper-Middle-Income economies[3]. Prior to the Covid 19 pandemic, SSA was home to five of the top ten fastest economies in the world, having recorded growth rates averaging between 4-6% percent from 2000 to 2018 giving it a new image as the rising continent, a sharp contrast to the scepticism of earlier decades when dictators ruled many countries with no accountability, social fabrics were ravaged by civil wars, institutions were fragile, and the continent was plagued with tepid economic growth (Brookings, 2011). However, economic growth in the region has slowed in the aftermath of the Covid-19 pandemic. While the number of cases and fatalities remain low, the economic impacts of the pandemic have been devastating. In 2021, an estimated 30 million people in the sub-region fell into extreme poverty and this has been exacerbated by economic disruptions stemming from the Russia-Ukraine war which is expected to render another 1.8 million people extremely poor in 2022, potentially reaching 2.1 million in 2023 (AfDB, 2022).

would then pursue the establishment of electricity markets as had been done in the pioneer reforming countries (Bergara et al., 1998; Kessides, 2012).

Over three decades since the initiation of reforms in SSA, electricity sector problems do not only persist, but have also become more complex and entrenched. An estimated 570 million people in the region are still without access to electricity. This represents about 45% of SSA population and about 75% of the global population without electricity access (World Bank, 2017). The 48 countries in the sub-region, with a population of about 1.1 billion have about 100 gigawatts of installed generation capacity, a level below that of Spain with a population of 46 million (World Bank, 2017). Estimates of annual electricity consumption per capita is about 485kWh on average, just enough to power a 60-watt light bulb for five hours a day (World Bank, 2017).

Electricity networks are unreliable, with an average of 102 outages a year (Masami and Trimble, 2016). Technical network losses are estimated to be about 11.7% of total supply, which is about twice that of OECD countries. Commercial losses due to metering and billing errors as well as power theft, are amongst the highest globally, as high as 65% in countries such as Liberia. Collection rates are also low, largely due to non-payment of public sector bills.

Despite being home to most people living in extreme poverty[4], SSA countries have the highest electricity prices for any region of the world, with an average end-user tariff of about US$0.12/kWh, nearly double the prices in the US and three times that of India (Blimpo and Cosgrove-Davies, 2019). However, these prices seldom cover the cost of energy supply, with electric utilities in the region only able to cover 60% of their operational costs on average (Masami and Trimble, 2016). Subsequently, utilities in the region are facing major financial difficulties, having to depend on government transfers to finance their operations.

The intractable nature of the problems in SSA electricity sectors indicate deeper structural issues that need to be understood and addressed. As the force behind prevailing electricity sector structures, institutions, and incentives, reforms provide a sturdy framework and reference point for assessing, contextualising, and addressing the challenges of SSA electricity sectors. Thus, the purpose of this thesis is to use reforms as a tool to identify the connections and interdependencies between electricity sector challenges in SSA to design holistic energy sector policies.

1.3. Research Aim and Questions

The aim of this thesis is to assess the performance of reforms in SSA and its relation to current sector challenges. Specifically, I assess the impacts of reforms on investments, technical efficiency, the rate

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[4] It is estimated that an estimated 41% of SSA population live on less than a $1.90 a day (World Bank, 2018)

of access expansion, and the cost of electricity services. This is achieved by answering three main questions:

i. What has been the impact of electricity sector reforms on investments and technical efficiency in SSA?
ii. What are the determinants of electricity access in SSA and how does reforms affect the rate of access expansion?
iii. How can cost-efficiency be achieved in liberalized electricity systems without competitive markets?

1.4. Contribution of Research

Despite extensive studies on reforms in developing countries, SSA remains the least studied region in the world, with quantitative studies on reforms almost non-existent (Jamasb et al., 2017). This thesis is one of the earliest panel data studies of reform performance in SSA. Studies such as the ones by Foster and Rana (2020), Erdogdu (2011, 2013), and Estache et al. (2008) are the few panel data studies on reform performance in SSA. However, these studies include a limited sample of SSA countries, with this study being the most comprehensive study on reform performance for the region.

This study also makes some methodological contributions in the assessment of reform performance. As noted by Kessides (2012), cross-country econometric assessments of the impacts of reforms on a set of defined performance measures remain limited because of model specification challenges and the inadequacy of current approaches in reflecting the multifaceted nature of the programme. Existing studies often use a modelling approach in which a single performance indicator of reforms is modelled as a function of a set of reform steps and country heterogeneities. This study presents a modelling break-through in this regard with the use of a Stochastic Frontier Analysis (SFA) approach and multi-input multi-output distance function approach in the assessment of reform performance. This modelling approach allows for the simultaneous assessment of multiple performance indicators of reforms across countries and overtime allowing the capturing of potential interdependencies and trade-offs that are common in multi-objective policy interventions, most unlikely to be captured in previous approaches.

The SFA approach used in this study is also more realistic as it does not compare the performance of SSA electricity sectors to an abstract ideal, but to a performance frontier that is endogenously determined and constructed from the sample. This modelling approach also allows for the incorporation of institutional variables, bringing our models as close to real conditions as possible. However, there are some limitations in the use of SFA and distance functions in the modelling of reforms. That is, the estimation of country-level reform efficiency is a function of the number of reform steps, with more reform steps expected to generate higher performance. Conceptually, this can be argued, as deeper reforms are expected to lead to better outcomes. This also implies that countries that achieve better outcomes with lesser reform steps are determined to be more efficient by this model, and subsequently countries that can achieve observed outcomes without implementing any of the reform steps are considered the best performers. We addressed this challenge by including in the analysis only countries that had implemented at least one reform step. However, it is important to iterate that electricity sector reforms is not a numbers game but a complex process that requires selectivity, careful sequencing, and strategic timing. Thus, this methodological approach has important value in this regard, as it allows for the observation of the most impactful reform steps or reform model, based on the approaches used by the best performing countries in the sample.

Panel data analyses of electricity access performance in SSA are also limited due to the prior lack of consistent and credible data on electricity access rates for countries in the region. Earlier studies on electricity access had to use weak proxies of access such as consumption per capita. This study is one of the earliest quantitative assessments on the determinants of electricity access in SSA, and the first to explore the nature of the connection between sector reforms and electrification programs. The study also provides some of the earliest quantitative evidence of the role of demand-side factors in electricity access with the inclusion of micro-level demand-side variables as explanatory variables (Blimpo and Cosgrove-Davies, 2019). By linking reforms and access, the study seeks to identify, activate, and leverage synergies to design holistic electricity sector policies.

Finally, this study brings an economic perspective to issues of cost under-recovery and poor financial performance of SSA power utilities to inform the design of policies that yields more sustainable outcomes.

1.5. Structure of thesis

The thesis is structured in a three-paper format, with each chapter dedicated to answering each of the research questions above.

In Paper One (Chapter two), I assess the performance of electricity sector reforms in 37 SSA countries between 2000 and 2017. I use a SFA approach to estimate a multi-input multi-output distance function in which a set of reform steps are considered as inputs to produce a set of outcomes which are indicators of reform performance after controlling for institutional heterogeneities across countries.

In Paper Two (Chapter three), I investigate the determinants of electricity access in SSA and its relationship to reforms using a production function and an SFA approach and data from 46 SSA countries from 2000 to 2017. The modelling of access performance also accounts for macroeconomic and institutional heterogeneities.

In Paper Three (Chapter four), I conduct a synthesis of cost efficiency in liberalized electricity systems without markets focusing on small electricity systems. I present an analysis of the key challenges of partially deregulated electricity systems drawing on various case studies across the region to establish connections between reforms, cost-recoverability, and the financial performance of sector utilities.

I conclude the study in Chapter five, presenting the findings of the study, the policy implications of these findings, and provide some recommendations for policy. I also outline the limitations of the study and suggest areas for future research.

2. Electricity Sector Reform Performance In Sub-Saharan Africa: *A Parametric Distance Function Approach*.

2.1. Introduction

Prior to reforms, the electricity sectors of SSA countries were beset with capacity shortages, low access rates, poor service quality, high technical and commercial losses, price-cost margins, and high subsidies (Wamukonya, 2005; Jamasb et al., 2017). Electricity sectors in the region were in dire need of investments, but access to finance was limited due to a global macroeconomic and debt crisis at the time. The traditional sources of finance for infrastructure projects (i.e., International Development Organisations) indicated unwillingness to continue supporting persistent underperforming structures and called for market-oriented reforms as a key condition to provide further support for electricity sector projects (World Bank, 1993, 2004).

During this period, there was also a global paradigm shift away for public monopoly market structures towards a market economy. The successes of pioneer reforming countries in other parts of the world including the US, UK, Chile, Argentina, and Norway, which was manifested in improved financial performance of utilities, lower electricity prices, and an expansion of choices available to consumers, encouraged SSA countries to implement reforms (Wolfram, 1999). This was buoyed by progress in Combined Cycle Gas Turbines (CCGT) technologies, which significantly reduced the efficient scale of electricity generation, and enhanced the prospects for wholesale competition and private sector participation in generation (Armstrong et al., 1994). These factors, together with the prospects of privatisation proceeds to amortise sector debts and restructure public sector liabilities, created a unique conjuncture to initiate electricity sector reforms in SSA.

In SSA, reforms were implemented in waves. The first waves focused on increasing generation capacity, improving the efficiency and availability of generation plants, optimizing the level of labour employment in utilities, reducing technical and commercial losses in the networks, eradicating subsidies, and promoting private sector participation in the delivery and management of electricity services. The idea was that, once the immediate challenges of low investments and productive inefficiencies have been effectively addressed, subsequent reforms would explicitly pursue the establishment of competitive markets to improve the welfare of consumers.

This study assesses the performance of reforms in delivering on its immediate objectives of facilitating investments and improving technical efficiency in SSA electricity sectors. It achieves this by modelling the impacts of a set of reform steps on core indicators of investment and technical efficiency - i.e., net installed generation capacity per capita; technical network losses; and plant load factor.

The remainder of this paper is organized as follows. Section 2 presents the literature review within the context of reform theory and performance. Section 3 defines the model and the econometric approach used in the study. Section 4 describes the data. Section 5 presents the results. Section 6 concludes the study with recommendations for policy.

2.2. Literature Review

Reforms in SSA involved a set of steps or measures based on a model template (Jamasb et al., 2006). These steps include (i) the enactment of an 'Electricity Law'; (ii) corporatization and commercialization of the core utility; (iii) the establishment of an independent regulatory authority; (iv) the unbundling of the core utility vertically and horizontally; and (v) private participation in the operations and management of electricity assets (Bacon, 1995, 1999; Bacon and Besant-Jones, 2001; Besant-Jones, 2006). This section discusses these essential reform steps in the context of underlying theoretical foundations and in the order of the preferred sequencing, i.e., legislation, regulation, restructuring, and private sector participation (Zhang et al., 2008; Besant-Jones, 2006). It also presents a review of key factors affecting reforms including the role of institutions and the starting point of reforms as well as relevant studies on reform performance in SSA.

2.2.1. Legislation and Regulation

The theoretical foundations of legislation during reforms can be found in the organizational economics literature. As explained by Coase (1960), in a world of positive transaction costs, legal rules matter for efficient outcomes (also see Dixit, 1996). Consequently, reforms are typically initiated with a legislative Act that sets out the general framework for restructuring, private sector participation, and the establishment and role of regulatory bodies (Jamasb et al., 2006). The Act signals commitment to implement reforms and reduces the uncertainty associated with property rights and contract resilience by setting out procedures for conflict resolution (Guasch, 2004). This provides the necessary assurances to private investors and reduces the risk of regulatory taking (Fischer et al., 2000).[5] In SSA, the Act also makes provisions for poverty-related programs such as electrification, subsidy schemes, energy efficiency and conservation, and renewable energy development.

Once the legal basis of reforms is established, policymaking and regulatory functions in the sector are separated. Policy formulation remains with the State while regulation is assigned to a newly established autonomous regulatory entity. The regulator is also given oversight over the reform process according to the provisions in the electricity law. The importance of this statutory regulator is critical, given the extensive evidence of a strong correlation between the effectiveness of the regulator and the progress and performance of reforms (Pollitt, 2009). Ghosh and Kathuria (2016) reiterate this in their study of Indian states, concluding that reforms are only as effective as the commitment of the regulator to implement it.

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[5] Regulatory taking is a situation when regulation limits the use of private property and deprives the property owners of economically reasonable use of their property, even though the regulation does not formally divest them of the title to it.

Economic regulation is necessary because the network segments of the ESI (i.e., transmission and distribution) have natural monopoly characteristics, making competition an ineffective mechanism for economic efficiency (Joskow and Tirole, 2005; Arrow, 1970; Shubik, 1970).[6] Theories of economic regulation postulate that institutional oversight could remedy this market failure through the imposition of rules backed by penalties (and or rewards) to modify the behaviour of actors in the industry (Posner, 1974). The sector regulator is subsequently charged to balance the interest of market participants, safeguarding the high sunk costs of investors while protecting consumers from monopoly exploitation. Kay and Vickers (1990) classify regulation into structural and conduct regulation. Structural regulation focuses on market structure through restrictions on entry and exit while conduct regulation focuses on the behaviour of market participants (Kay and Vickers, 1990). In the electricity sector, regulation encompasses both. It also extends beyond the natural monopoly segments to cover the competitive segments to dissuade anticompetitive practices by dominant incumbents (Armstrong et al., 1994).

In addition, public interest theory notes the relevance of regulation beyond imperfect competition, unbalanced market operations and missing markets to encompass the prevention and correction of undesirable market results (den Hertog, 1999; Cubbin and Stern, 2006). This is generally in the form of social regulation as per considerations of justice, paternalistic motives, or ethical principles (Kim and Mahooney, 2005). In SSA, this includes consumer safeguards against predatory pricing and quality regulation. Trade-offs can arise in the regulatory decisions, for instance between economic efficiency and equity, and the incentive effects of redistribution can result in a decline in the level of individual utility (Kim and Mahoney, 2004; Okun, 1975).

Green (2005) categorises regulatory best-practice into three aspects; (i) the form of regulation which relates to the powers and responsibilities of the regulatory agency, (ii) the process of regulation which refers to ways that the agency carries out its activities and (iii) the outcome of regulation, which refers to the measurement of success for a regulatory agency. Larsen et al. (2006) provides a comprehensive account of European Union regulators and concluded that the most effective regulators had more independence and control over the important elements of the regulatory process. The setting of regulatory rules ex-ante has been indicated to be better for investment and decision-making as it limits the scope for political intervention (Pollitt, 2009). However, Fischer et al. (2000) notes that placing much of the decision-making power in the electricity law may weaken the regulator and its flexibility to adapt to changing conditions during the reform process. Pardina and Schiro (2018) also highlight the importance of balancing autonomy with accountability to ensure regulators are obliged to all stakeholders (Foster and Rana, 2020).

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[6] In a broader sense, regulation refers to rules, directives or discretionary authority that determine the market structure of markets and/or guide the conduct of economic activities. These rules may be stipulated by a contract and/or legislation (Teplitz-Sembitzky, 1990; Joskow, 2005).

The efficacy of the electricity sector regulator is usually reflected in the competence with which it carries out its tasks (Pollitt, 2009; Noll, 1989; Stern and Holder, 1999). The regulator should be procedurally efficient, following a regular pattern especially with regards to work plans and tariff reviews. It should also be abreast with best-practice methodologies and benchmarking techniques to design appropriate incentives, especially for the non-price elements of performance such as quality of supply.

2.2.2. Restructuring – Unbundling, Corporatization, and Commercialization

In the next instance, the ESI is vertically unbundled- i.e., separating the potentially competitive activities (generation and retailing) from the natural monopoly segments (transmission and distribution). It is essential that unbundling takes place with due consideration of the political, social, and economic contexts of the reforming country to avoid creating conditions that may complicate the reform process or worsen the welfare of consumers (Scherer and Ross, 1990; Jamasb, 2006).

Earlier reforms (in other developed countries) typically began with the separation of the generation segment (see for instance, Rufin, 2003). This is largely because deregulation efforts were often in pursuit of efficiency in the generation segment. In SSA, however, most of the inefficiencies in the sector were in the distribution segment, with the main problems in generation segment being the lack of investments. As a result, vertical unbundling often began with the separation of the distribution business and its inefficiencies, as not separating that segment could jeopardize potential gains in other parts of the ESI (World Bank, 2004). Following this, the distribution utility may be horizontally unbundled to facilitate yardstick competition and provide the regulator with multiple sources of information for effective regulation of the segment (Jamasb, 2006).

Then, the transmission activity is separated, a critical step for promoting private sector investments in generation as it facilitates non-discriminatory third-party access to the grid (Jamasb et al., 2005; Joskow, 1998a, 1998b). However, this separation disrupts real-time coordination of electricity sector activities, making it necessary to appoint a system operator to oversee power scheduling and dispatching. Some reform scholars advocate for ownership unbundling of transmission (Hunt, 2002; Joskow, 2006a, 2006b; Newbery, 1997, 2003). However, given the institutional limitations of most SSA countries, it is recommended that the grid remains in state ownership (Jamasb et al., 2005, Jamasb, 2006). Nonetheless, the regulator should define the rules of grid access which should preferably be regulated third-party access at this stage. It is important that the grid has adequate capacity to support the reforms during the initial years to prevent network congestion, which could serve as a barrier to new entry and hinder competition (Jamasb et al., 2005). In addition, investments in generation without corresponding investments in the networks could result in increased technical losses, service interruptions, and poor service quality.

While vertical unbundling begins with the separation of the distribution business, liberalisation of the ESI of SSA countries often begins in the generation segment. This is typically in the form of the introduction of Independent Power Producers (IPPs), often preceding the unbundling of the sector. Consequently, a vertically integrated electricity sector with IPPs is a common electricity sector structure in SSA. The generation segment may be split into several units to remove the dominance of the incumbent and create an adequate number of firms for wholesale competition. However, this is not necessarily assured given that in the UK, the initial split of fossil fuel-based generation assets into two competing companies proved inadequate in generating effective competition (Pollitt, 2009). In SSA, the ownership and management of generation assets that existed prior to reforms are often retained by the vertically integrated utility. IPPs sell the power they produce to this utility or to a designated off-taker, which may be the vertically unbundled distribution utility or a designated bulk power purchasing authority such as in the case of Nigeria.

The retail segment may then be unbundled vertically and horizontally. However, as explained by Armstrong et al. (1994), retail competition requires sophisticated metering technologies and an adequate market size. Without these structures, smaller customers of regional distribution companies are essentially captive. It is thus unsurprising that no SSA electricity system has unbundled their retail segment.

Finally, the successor utilities are corporatized[7] to instil good commercial practices and to prepare for a subsequent redefinition of property rights if desired (Bacon, 1999). This allows for legal protection and third-party enforcement which is absent under state ownership (Alchian, 1965).

2.2.3. Private Participation and Property Rights

The arguments for private ownership and management of electricity assets are underscored in property rights theories. Property rights (which may be secured through the judicial system or the regulatory process) are believed to provide economic incentives that shape resource allocation. Private enterprises are driven by the desire for profits and may have more professional know-how in management, operating procedures, and the use of appropriate technologies (Guasch, 2004). Thus, private participation in the electricity sector would create new production possibilities and efficiency improvements that could be captured and appropriated for the benefit of consumers (Alchian, 1965;

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[7] Corporatisation refers to transforming state assets and entities into corporations typically with the corporate structure of publicly traded companies. In the electricity sector, this involves the incorporation of the successor utilities as limited liability entities with the government often retaining majority ownership. It may involve delegated public joint stock, and publicly listing of companies to introduce corporate and business management techniques. These companies tend to have a board of directors, management, and shareholders. Almost all SSA countries have undertaken this reform step.

Demsetz, 1966, 1967, 1988). Furthermore, privatization makes it difficult for Governments to interfere in enterprise operations, making the sector less vulnerable to political patronage (Guasch, 2004).

The general position is that public ownership is superior to private ownership under very few circumstances (Hart et al., 1997; Megginson and Netter, 2001; North, 1990a, 1990b). Earlier reforms were quite optimistic about the evolution electricity sectors towards economic efficiency with sector privatization. However, there are several examples of the failures of privatization to deliver anticipated economic efficiency gains (Jamasb et al., 2006; Zhang et al., 2005; Estache et al., 2001; Freije and Rivas, 2003; McKenzie and Mookherjee, 2003. A notable example is the case of the Nigeria electricity sector which has been fully privatized since 2006 but significant inefficiencies persist. On the other hand, Norway maintains government ownership and remains one of the well-functioning electricity systems in the world (Jamasb, 2006).[8] With several of such examples globally, the consensus in the reform literature is that privatization is not a sufficient reform step for improved economic efficiency (Jamasb, 2006).

Furthermore, ownership of electricity assets has national security implications due to the pervasive nature of electricity in all aspects of the economy. Consequently, governments in SSA are typically reluctant to transfer the ownership of electricity assets to the private sector permanently and tend to lean towards temporary transfer of property rights. This often involves the transfer of specific economic rights to electricity assets or aspects of it to a private party without changing the ownership structure of the asset (Foss and Foss, 2001; Coase, 1960). Innovative Public-Private Partnership (PPP) models in the forms of Management Service Contracts (MSC), Affermage contracts, and Concessions have made such impermanent transfers of property rights possible and common across the region (World Bank, 2004).[9] However, different specifications of property rights have different effects on economic behaviour and outcomes as they provide different levels of incentives (Kim and Mahoney, 2005; Coase, 1960; Pejovich, 1979, 1982). Nonetheless, if privatization is desirable and feasible, it should ideally start with the distribution segment as it signals to potential investors a commitment to instil commercial discipline in the sector.

2.2.4. The Role of Institutions, System Size, and Initial Sector Structure in Reforms

North (1991) defines institutions as “humanly devised constraints that structure political, economic, and social interactions”. These constraints can be informal such as sanctions, taboos, customs, traditions, and codes of conduct, or formal such as constitutions, laws, and property rights (North, 1991). The interactions of these factors form the institutional environment, and together with the standard

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[8] There is no doubt several other factors that accounts for this disparity between these two countries, but it does indicate that the private sector may not necessarily be the solution in some institutional contexts.

[9] See the World Bank PPP database for more details on the various forms of public-private partnerships.

constraints of economics define the choice set that determine transaction and production costs, and subsequently the profitability and feasibility of engaging in an economic activity (North, 1991).

With respect to reforms, Jamasb et al. (2014) refers to institutional factors as the sector and macro-level legal and regulatory frameworks that influence and support the continuity of the reform process. Reforms generally involve politically unattractive requirements, which makes commitment to the process difficult to secure and sustain. Consequently, the sector transformation process and its outcomes at each stage is very fragile and highly susceptible to the local political economy. In SSA, reforms take place within institutional settings that are characterized by unstable political systems, interventionist governments, unclear legislation on property rights, limited accountability, lack of judicial credibility and corruption (Imam, 2019a; Jamasb, 2006; Laffont, 2005). During the reform process, it is therefore imperative that governments demonstrate political and legislative leadership as well as sustained commitment to the necessary regulatory and institutional changes. Policymakers must make realistic assumptions during the formulation of reforms to ensure alignment of the program with the institutional attributes of the country (Levy and Spiller, 1994; Bergara et al., 1998).

The role of institutional quality on various aspects of economic performance has emerged in various analyses (Imam et al., 2019a, 2019b; Erdogdu, 2013; Nepal and Jamasb, 2012). The literature identifies two main approaches to institutional economics, i.e., the incentives approach and the governance approach. In distinguishing between incentives and governance, Levy and Spiller (1994) refer to incentives as the rules related to utility pricing and subsidies, and governance as how credible commitments are generated.

Ghosh and Kathuria (2016) explain that while earlier emphases had been on incentives in the earlier literatures (Loeb and Magat, 1979; Laffont and Tirole, 1993), the new institutional economics is concerned with governance (Tommasi, 2006; Tommasi and Velasco, 1996). Kaufmann et al. (1999, 2009) explain that governance is not randomly distributed across countries, but good governance requires time and resources to develop, with wealthier countries more likely to enjoy better governance (also see Kraay et al., 2010). Mahoney (2004) adds that good governance is a function of a country’s political and social history, and in SSA it is often shaped by the colonial heritages of countries.

In liberalized electricity sectors, the quality of the sector regulator has been indicated to be a good reflection of the institutional capacity or governance capabilities of the ESI and the country in general (Cubbin and Stern, 2006; Ghosh and Kathuria, 2016; Estache and Wren-Lewis, 2009). This is particularly important in the SSA context where reforms depart significantly from the standard models. However, capture theory asserts that overtime, regulation will come to serve the interests of the branch of the industry it governs (Kim and Mahooney, 2005). The regulator may tend to avoid conflicts with the regulated company because it is dependent on it for its information while there are career opportunities for the regulators (personified) in the regulated companies (Den Hertog, 1999).

Successful reforms do not only require strong institutions but also governance structures that are based on good principles, decisive leadership, and human resources. Graham et al. (2003) defines governance as “structures, processes and traditions that determine how power and responsibilities are exercised, how decisions are taken, and how citizens or other stakeholders have their say”. It is a social function involving the establishment and administration of rights, rules, and decision-making procedures to direct socio-ecological systems along pathways that are collectively desirable (Graham et al., 2003). It is designed to, amongst others, generate social capital needed to solve a variety of collective-action problems (Delmas and Young, 2009).

In many SSA countries, weak institutions and poor governance further complicate the reform process and its outcomes. This often manifests in lack of policy coherence on reforms, ambiguity in long term reform goals, inadequate human resources and lack of accountability. In many SSA countries, there are large regulatory gaps and legal loopholes that make monitoring and evaluation challenging and accountability difficult to enforce. As a result, corrupt practices and rent-seeking behaviours are a common feature of reforms (see more details in chapter 4).

In addition to these institutional considerations, there are other sectoral factors that may affect reform processes and performance. One such factor is the size of the electricity system which has been indicated to hinder the implementation of reforms (Bacon, 1995). There have been arguments that the benefits of a full reform package may be small in relation to the costs in small electricity systems as the case for unbundling gets weaker as the electricity system gets smaller (Bacon, 1995; Besant-Jones, 2006; World Bank, 2004; Hunt, 2002).

In addition, hydrological factors have become important in SSA electricity systems, with the prevalence of droughts and other climatic changes (Koch et al., 2016). As at the end of 2018, the International Hydropower Association estimated that SSA had about 36,264 megawatts (MW) of hydroelectric generation capacity, representing over 20 percent of installed generation capacity (International Hydropower Association, 2020). Thus, hydrological factors that decrease water discharge and availability in hydropower plants have important implications for plant availability and the performance of the sector (Cole et al., 2014; Blimpo and Cosgrove-Davies, 2019).

2.2.5. Reform Performance in sub-Saharan Africa

Jamasb et al. (2005) identify three main approaches for evaluating ESR performance. These include econometric methods, efficiency and productivity analysis, and individual and comparative case studies. The study indicates that econometric studies are best suited for well-defined issues and hypotheses while efficiency and productivity analysis (which can be based on econometric methods) are preferred for measuring the efficiency of transforming inputs into outputs relative to best practice (Jamasb et al., 2005). Case studies, which are typically conducted at macro (country) or micro (household or firm) levels are suitable when conducting an in-depth investigation and qualitative analysis.

As discussed earlier, the principal push-factor for reforms in SSA was the urgency to transfer the investment burden onto the private sector. Thus, the earliest waves of reforms focused on liberalizing the sector to facilitate investments while improving technical efficiency which has been indicated to be compatible with other economic efficiency objectives (Wolfram, 1999; Pestieau and Tulkens, 1993). Studies have shown that utilities of countries that reformed their electricity sectors performed better in terms of technical efficiency than those that did not, predicated on the combination and in some cases the sequencing of reform steps (Zhang et al., 2005).

Plane (1999) evaluated the impact of the privatization of the Ivorian vertically integrated electricity utility (defined by a ten-year MSC) on technical efficiency. The study utilized pre-reform and post-reform time series data from 1959-1995 using an SFA approach. The parametric and non-parametric tests performed could not reject the hypothesis of significant technical efficiency improvements after signing the contract although the performance was irregular over the period. However, the results also indicated that technical efficiency never reached the levels of the 1970s when the company was under close government supervision.

Estache et al. (2008) utilized Data Envelopment Approach (DEA) to evaluate the changes in Total Factor Productivity (TFP) for a sample of 12 operators in the Southern Africa Power Pool (SAPP) between 1998 and 2005. The results indicated a slight improvement in TFP although the study could not establish that the efficiency improvements were due to the reforms. However, the findings suggested that although the companies had not utilized their capital and human assets better, they had adopted better technologies and commercial practices.

A panel data analysis by Erdogdu (2011) for 92 countries including eight countries in SSA from 1982 to 2008 found statistically significant but limited effect of reforms on plant load factor and network losses after controlling for country-specific variables such as GDP.

2.3. Methodology

Ordinary Least Squares (OLS) and some of their variants have traditionally been used in production economics to estimate functions (e.g., production or costs functions) that pass through the mean of the observed values in the sample. In the early 1950s, a persuasive argument was made that although producers may indeed attempt to optimize, not all are successful in doing so. OLS delivered estimates of models in which the ‘average’ rather than the ‘best-practice’ behaviour of producers was described. Thus, it provided information about the technology but not on the efficiency of the production process. This mooted discussions on how production functions were estimated, giving rise to the proposal and application of frontier analysis techniques.

Frontier methodologies are based on the theoretical premise that a production frontier (or its dual, the cost frontier) represents an ideal of best practice that an economic agent cannot exceed, and deviations from this, represent inefficiencies. Consequently, it theorizes that a producer is 'technically' efficient, if and only if it is impossible to produce more of any output without producing less of some other output or using more of some inputs (Koopman, 1951; Cooper et al., 2006). Frontier approaches may be parametric in nature, as SFA; nonparametric such as Data Envelopment Approach (DEA); or even semi-parametric such as the Stochastic Nonparametric Envelopment of Data (StoNED) proposed by Kuosmanen and Kortelainen (2012).

2.3.1. A Stochastic Distance Function to Measure Reform Performance

SFA models originated from the near-simultaneous publications by Aigner et al. (1977) and Meeusen and van den Broeck (1977). In these papers, the production frontier is modelled as an equation expressed as $y = f(x, \beta)\exp(v - u)$, where y is an output, x is a vector of inputs, β represents parameters to be estimated and '$v - u$' represents a convoluted error term. The first part of this error term, v, is a two-sided random disturbance that captures the effects of statistical noise and measurement errors associated with the functional form, while the term u is a one-sided random term that captures technical inefficiency.[10]

When multiple outputs are produced using multiple inputs, Shephard (1953, 1970) distance functions provide a functional characterization of such a production technology. Distance functions allow for the description of a production technology without explicitly specifying any behavioural objective (Lovell, 1996; Kumbhakar and Lovell, 2000; Coelli et al., 2005). Distance functions can be input-oriented or output-oriented. Output (input) distance functions are used when outputs (inputs) are endogenously determined in the model. Output (input) distance functions provide an indication of the maximal (minimal) proportional expansion (contraction) of the output (input) vector given an input (output) vector (Kumbhakar et al., 2007; Coelli et al., 2005).

In this study, I propose an output distance function to estimate the efficiency with which SSA countries have translated reform steps and some institutional features into sector-level performance outcomes.[11]

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[10] These error terms are assumed to be identically distributed across observations, distributed independently of each other and uncorrelated with the explanatory variables.

[11] Distance functions provide the conceptual underpinning for efficiency and productivity analysis in different industries. Some studies present applications to the electricity sector. E.g., Estache and Rossi (2005) and Ghosh and Kathuria (2016); Perelman and Santin (2008). Moreover, our model can also be interpreted under a 'benefit-

If a vector of reform steps is defined as $x = (x_1, \ldots, x_K)$ and a vector of reform outcomes as $y = (y_1, \ldots, y_M)$, where $m = 1, \ldots, M$ and $k = 1, \ldots, K$ represent the number of outputs and inputs respectively, one can then specify a feasible multi-input multi-output production technology using the outcome set $P(x)$ that can be produced using the vector of reform steps, x, such that $P(x) = \{y: x \text{ can produce } y\}$, and it is assumed to satisfy the set of axioms depicted in Färe and Primont (1995). As proposed by Shephard (1970), such an outcome distance function can be defined as:

$$D_O(x, y) = \min\{\varphi: (y/\varphi) \in P(x)\} \qquad (1)$$

where φ represents the minimum scalar by which all the outcomes can be proportionally divided while remaining in the feasible production set. Färe and Primont (1995) demonstrate that such an outcome distance function has the following characteristics: (i) it is linearly homogenous in y; (ii) it is non-decreasing in y and non-increasing in x; (iii) it is convex in y and quasi-convex in x; and (iv) if the distance function $D_O(x, y)$ takes a value less than or equal to 1, then y belongs to the feasible production set $P(x)$ such that $0<\text{TE}\leq 1$. Consequently, when a firm is operating on the frontier, it has a distance function value equal to unity and consequently a technical efficiency score of 1.

Utilising a flexible functional form like the transcendental logarithmic (translog) specification, the model can be expressed as:

$$\ln D_{Oit}(x, y) = \alpha_0 + \sum_{m=1}^{M} \alpha_m \ln y_{mit} + 0.5 \sum_{m=1}^{M} \sum_{n=1}^{M} \alpha_{mn} \ln y_{mit} \ln y_{ni} + \sum_{k=1}^{K} \beta_k x_{kit}$$
$$+0.5 \sum_{k=1}^{K} \sum_{l=1}^{K} \beta_{kl}\, x_{kit} x_{lit} + \sum_{k=1}^{K} \sum_{m=1}^{M} \delta_{km} \ln x_{kit} \ln y_{mit}\,, \quad i = 1, \ldots, N \qquad (2)$$

where α, β and δ are parameters to be estimated, i indicates the ith observation in the sample, t represents the tth time period, and all other variables are defined as before. The frontier surface can then be defined by setting $D_O(x, y) = 1$ which implies that $\ln D_O(x, y) = 0$. This equation must satisfy the conditions of symmetry and homogeneity of degree +1 in outputs. The symmetry condition is met if $\alpha_{mn} = \alpha_{nm}$ and $\beta_{kl} = \beta_{lk}$, and the homogeneity condition is met if $\sum_{m=1}^{M} \alpha_m = 1$, $\sum_{n=1}^{M} \alpha_n = 0$ and $\sum_{n=1}^{M} \delta_{km} = 0$. Following Lovell et al. (1994), homogeneity of degree +1 can be imposed by normalizing the output distance function by one of the outputs arbitrarily chosen, e.g., y_M. This transforms equation (2) into the following expression:

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of the-doubt' approach (see Cherchye et al., 2007). In that sense, our model serves to identify the outcomes deemed as most important by reforming countries.

$$\ln\left[\frac{D_{Oi}(x,y)}{y_{Mit}}\right] = \alpha_0 + \sum_{m=1}^{M-1} \alpha_m \ln\left(\frac{y_{mit}}{y_{Mit}}\right) + 0.5 \sum_{m=1}^{M-1}\sum_{n=1}^{M-1} \alpha_{mn} \ln\left(\frac{y_{mit}}{y_{Mit}}\right) \ln\left(\frac{y_{nit}}{y_{Mit}}\right) + \sum_{k=1}^{K} \beta_k x_{kit}$$

$$+0.5 \sum_{k=1}^{K}\sum_{l=1}^{K} \beta_{kl}\, x_{kit} x_{lit} + \sum_{k=1}^{K}\sum_{m=1}^{M-1} \delta_{km}\, x_{kit} \ln\left(\frac{y_{mit}}{y_{Mit}}\right), \quad i = 1, \ldots, N \qquad (3)$$

After rearranging terms, equation 3 can be rewritten as:

$$-\ln(y_{Mit}) = TL\left(x_{it}, \frac{y_{it}}{y_{Mit}}, \alpha, \beta, \delta\right) - \ln D_{Oit}(x,y) \qquad (4)$$

where $-\ln D_{Oit}(x,y)$ represents the radial distance from the boundary, i.e., deviations from optimal production levels. $-\ln D_{Oit}(x,y)$ is set to equal u which represents the inefficiency term, and a noise term, v, is added to capture statistical noise. This transforms equation (4) into the traditional stochastic frontier model proposed by Aigner et al. (1977) and Meeusen and van den Broeck (1977). This error term is assumed to be a normally distributed, and the u component follows a half-normal distribution.[12] Some control variables are also added to capture sector and country heterogeneities that may impact the process of transforming reform steps into performance (See details in Section 2.4).

We consequently obtain the following equation:

$$-\ln(y_{Mit}) = TL\left(x_{it}, \frac{y_{it}}{y_{Mit}}, \alpha, \beta, \delta, \omega, K_{it,}\right) + v_{it} + u_{it} \qquad (5)$$

where K is the vector of control variables and ω is the vector of parameters linked to the control variables.

In this study, I am also interested in identifying sources of inefficiency in the process of transforming reform steps into performance. However, the inefficiency term in Aigner et al. (1977) model described before has a homoscedastic constant variance, i.e., $u_{it} \sim N^{+}(0, \sigma_u^2)$ which does not allow for the incorporation of the determinants of inefficiency. Estimates from such models can yield biased estimates of both frontier coefficients and country-specific inefficiency scores (Caudill and Ford, 1993). This issue can be addressed using a heteroscedastic frontier model that allows for the incorporation of variables as inefficiency determinants through the pre-truncation variance of the inefficiency term, u.[13] (Details in Section 2.4). Thus, equation (5) can be rewritten as:

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[12] In order to estimate the model, some assumptions have to be made about the distribution of the inefficiency term. Aigner et al. (1977) assumed a half-normal distribution while Meeusen and van den Broeck (1977) opted for an exponential distribution. Other commonly adopted distributions are the truncated normal (Stevenson, 1980) and the gamma distributions (Greene 1980a, 1980b, 1990).

[13] For a discussion on the alternatives to introduce inefficiency determinants in SFA and an application to the electricity sector, see Llorca et al. (2016).

$$-\ln(y_{Mi}) = TL\left(x_i, \frac{y_i}{y_{Mi}}, \alpha, \beta, \delta\right) + v_{it} + u_{it}(z_{it}, \vartheta) \qquad (6)$$

where Z are the determinants of the inefficiency term and ϑ are the parameters associated with the inefficiency determinants to be estimated.

2.4. Data

The study utilizes a dataset that comprises an unbalanced panel of 37 SSA countries[14] from 2000 to 2017. In total, the number of observations is 512. The countries included in our analysis have implemented at least one reform step during the period of observation. Data used in this study were obtained from the United Nations and World Bank databases as well as online resources of relevant sector institutions in the countries.

We consider three main reform steps as inputs - i.e., the presence of an electricity law, vertical unbundling of the ESI, and the presence of an autonomous sector regulator. Private ownership and participation in the management of the electricity sector is included as a control variable and not as an input. This is because this reform step is typically implemented to improve the operational and managerial performance of utilities and not to increase installed generation capacity, improve plant load factor or reduce technical network losses as is the focus of this assessment. However, perceptions of the financial and operational performance of electricity sector utilities influence investment decisions, justifying the inclusion of this reform step in the model as a control variable.

The reform variables considered are dummies that take value 1 in case the reform step has been implemented, and 0 otherwise. Table 2.4-1 presents the descriptive statistics of these variables, with details in Appendix 1.1.

Table 2-1: Description of reform steps (Inputs and Control Variables).

Reform Steps (Inputs).	**Description**	**Descriptive Statistics**
Electricity law ***act***	The presence of a law that liberalised the electricity sector	Max = 1 Min = 0 Mean = 0.87 St. Dev. = 0.33

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[14] Angola, Benin, Botswana, Burkina Faso, Cabo Verde, Cameroon, Democratic Republic of Congo, Cote d'Ivoire, Equatorial Guinea, Eritrea, Eswatini, Ethiopia, Gabon, The Gambia, Ghana, Guinea, Kenya, Liberia, Lesotho, Liberia, Malawi, Mali, Mauritania, Mozambique, Namibia, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, South Africa, Tanzania, Togo, Uganda, Zambia, Zimbabwe.

Vertical unbundling ***unb***	Legal unbundling – separation of the generation, transmission and coupled distribution and retail segments.	Max = 1 Min = 0 Mean = 0.18 St. Dev. = 0.38
Sector regulator ***reg***	The presence of an autonomous sector regulator.	Max = 1 Min = 0 Mean = 0.74 St. Dev. = 0.44
Control Variable		
Private participation ***pi***	Private participation in parts or all segments of the ESI in the form of Management Service Contracts, leases/affermage contracts, concessions, and divestments.	Max =1 Min = 0 Mean = 0.26 St. Dev. = 0.44

Source: Compiled by the author.

We consider three performance indicators as outcomes. These include the level of installed generation capacity per capita, the load factor of the generation portfolio, and the level of technical network losses. These outputs were specifically chosen to denote the level of investments in the ESI and the technical efficiency of sector assets, as per the aim of the first wave of reforms. Table 2.4-2 provides the descriptive statistics of the outcome variables and Appendix 1.2 provides more details.

Table 2-2. Description of performance indicators (Outputs).

Performance Indicator (Output)	**Description**	**Descriptive Statistics**
Installed Generation Capacity per Capita ***gencap***	Measures the level of investment per capita in the generation segment. It is calculated as (Net Installed Generation Capacity in kW / total population). It is measured in kilowatt hour.	Max =1.61 Min = 0.01 Mean = 0.12 Std. Dev.= 0.19
Plant Load Factor ***plf***	Measures the efficiency of the generation assets. It is calculated as (total electricity production / (Net installed generation capacity*number of hours in the year). It is measured in percentage.	Max = 0.88 Min = 0.05 Mean = 0.41 Std. Dev.= 0.15

Transmission and Distribution Losses ***losses***	Measures the efficiency of transmission and distribution assets. It is calculated as the sum of technical network losses divided by total electricity supply (where supply is the sum of domestic production and net imports).[15] It is measured in percentage.	Max= 0.58 Min= 0.032 Mean= 0.07 Std. Dev.= 0.16

Data Source: United Nations Database.

Control Variables and Inefficiency Determinants

In order to capture the effects of institutions and sector heterogeneities on reform performance, five control variables are included in the model (Refer to Section 2.3.1). These include installed generation capacity (as a proxy for system size) and the size of hydroelectric capacity to capture the effects of hydrological changes. In addition, three aspects of the World Bank Governance Index (WGI) are included to capture the effects of institutions. These are the Political Stability and absence of Violence and Terrorism, Regulatory Quality, and Governance Effectiveness indicators.

Finally, five determinants of inefficiency are included. These are the two sector-level control variables, i.e., generation capacity and the private ownership and management variables. This is in addition to the corruption indicator of the WGI, the level of hydropower in the generation portfolio and the regulator dummy to explore potential impacts of regulatory risks on reform performance. Table 2.4-3 summarizes the control variables and inefficiency determinants.

Table 2-3. Description of Institutional Variables and other sectoral characteristics. (Control Variables and inefficiency determinants)

Control Variables and Inefficiency Determinants	**Description**	**Descriptive Statistics**
Regulatory Quality ***rq***	This is a dimension of the WGI which captures perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development.	Max = 4.30 Min = 1.26 Mean = 2.94 St. dev = 0.55

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[15] It is important to note that several databases measure technical network losses as a percentage of total production instead of total supply (i.e., production plus net imports). Where there are cross-border power exchanges, this results in an overestimation of the technical network losses.

Governance Effectiveness ***ge***	This is a dimension of the WGI which captures perceptions of 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 government commitment to such policies.	Max = 0.73 Min = -1.73 Mean = 0.66 Std. dev. = 0.52
Political Stability and Absence of Violence ***ps***	This is a dimension of the WGI which captures perceptions of the likelihood of political instability and/or politically motivated violence, including terrorism.	Max = 4.72 Min = 1.24 Mean = 3.13 Std. dev. = 0.76
Control of Corruption ***cc***	This is a dimension of the WGI which captures perceptions of the extent to which 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. An increase in this variable implies that a country is less corrupt, and a decrease implies that a country is more corrupt.	Max = 1.04 Min = -1.81 Mean = 0.54 Std. dev. = 0.59
Hydroelectric Capacity ***hydro***	Installed hydroelectric capacity (MW).	Min = 0 Max = 3,814 Mean = 522.31 Std. dev = 702.67
Net Installed Generation Capacity (MW) ***gc***	This refers to the size of the generation capacity (MW). It serves as an indicator for the size of the electricity sector.	Max= 53,028 Min=14.3 Mean= 2,349 Std. dev= 7,698
Note that ***hydro*** is introduced in the model both as a control variable in the frontier and as an inefficiency determinant.		

Data Source: World Bank and United Nations Databases.

2.5. Results and Discussion

Production theory assumes that output-oriented distance functions should satisfy the curvature and monotonicity conditions previously described.[16] As a direct consequence, the coefficients of outcomes

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[16] For further discussion on the imposition of these constraints, see Coelli et al. (2005).

(β) are expected to be positive and that of the reform steps (α) are expected to be negative for this type of distance function.[17] These coefficients can be interpreted as distance function partial elasticities with respect to outcomes and reform steps at the sample mean. However, *losses* represent a "bad output", as an increase in this variable does not imply an improvement in sector performance but rather a reduction is a positive outcome. Thus, I modified the data by negating the losses data to denote this and facilitate easier presentation of results. With this change, the coefficient of the *losses* variable is expected to be negative and the coefficients of *plf* and *gencap* to be positive.

Table 2.4-4 presents the parameter estimates of three specifications of the output distance function utilized in this study, i.e., the Cobb-Douglas, a translog without inefficiency determinants and a translog with private participation, the presence of a regulator, the size of the electricity sector, control of corruption, and the level of hydroelectric capacity in the generation mix as inefficiency determinants. The results of all the model specifications are presented but only the results of the translog model with inefficiency determinants are discussed since this latter model is the preferred one.[18]

As can be seen in Table 2.4-4, the estimated first order coefficients of the performance indicators, i.e., *gencap* and *plf*, are positive and statistically significant, and that of *losses* is negative and statistically significant. The positive coefficient of *gencap* indicates that reforms are correlated with increased rate of investments in the generation segment of the SSA electricity sectors above the growth in population. This finding is in line with studies such as the ones by Eberhard et al. (2017) and Foster and Rana (2020) which notes the surge in IPPs in SSA around the early 2000s [19]

Table 2-4. Parameter Estimates.

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[17] The parameters of the model are estimated using the maximum likelihood procedure. As I use the variable *gencap* to impose homogeneity, the dependent variable of the model is –log (*gencap*). In order to facilitate the interpretation of the estimated parameters, the output variables have been transformed into deviations to their mean values after taking logarithms.

[18] I carried out Likelihood Ratio (LR) tests to compare the three models presented in Table 4. The test value when comparing the Cobb-Douglas and the translog without inefficiency determinants is 146.41***, while the values of the test when comparing the translog with inefficiency determinants against the Cobb-Douglas and the translog without inefficiency determinants are respectively 215.60*** and 69.19***. These values confirm that both the Cobb-Douglas and the translog without inefficiency determinants are rejected in favour of the translog with inefficiency determinants, and hence I consider the latter as the preferred model.

[19] 49% of Chinese investments in the power sector between 2010 to 2020 was in hydropower projects (International Energy Agency, 2016).

Variable	**Cobb-Douglas**		**Translog**		**Translog with Inefficiency Determinants**	
	Coefficient	***Std. Error***	***Coefficient***	***Std. Error***	***Coefficient***	***Std. Error***
Frontier						
Outputs						
log (*gencap*)	0.89		-0.97		0.83	
log (*plf*)	0.50***	0.03	0.49***	0.08	0.58***	0.08
log (*losses*)	-0.39***	0.03	-0.52***	0.08	-0.41***	0.07
Inputs						
act	0.02	0.04	-0.23***	0.08	-0.23**	0.08
unb	-0.14***	0.03	-0.43**	0.21	-0.47**	0.18
reg	0.00	0.02	-0.32***	0.09	-0.37***	0.09
Control Variables						
pi	-0.14** *	0.02	-0.10***	0.02	-0.21***	0.04
rq	-0.04	0.02	0.08	0.04	0.06	0.04
ge	-0.05	0.05	-0.05	0.05	-0.04	0.05
ps	-0.06***	0.02	-0.12***	0.02	-0.09***	0.02
hydro	-0.00***	0.00	-0.00***	0.00	-0.00 ***	0.00
Log(gc)	-0.00	0.01	-0.04	0.01	-0.00	0.01
Output Interactions						
0.5 (log *plf*)^{2}			0.25***	0.06	0.21***	0.05
0.5 (log *losses*)^{2}			0.26***	0.04	0.23***	0.04
log (*plf*)* log (*losses*)			-0.29***	0.04	-0.27***	0.04
Input Interactions						
*act*unb*			0.36*	0.20	0.36**	0.17
*act*reg*			0.26***	0.08	0.26***	0.08
*unb*reg*			0.05	0.09	-0.08	0.10
Inputs-Outputs Interactions						
(log *plf*)**act*			-0.18**	0.06	-0.25***	0.08
(log *plf*)**unb*			-0.18*	0.09	-0.14*	0.09
(log *plf*)**reg*			0.32***	0.05	0.28***	0.05
(log *losses*)**act*			0.09	0.05	0.16***	0.06
(log *losses*)**unb*			0.08	0.07	0.07	0.08
(log *losses*)**reg*			-0.35***	0.04	-0.29***	0.04
intercept	-0.34***	0.05	0.05	0.09	0.16*	0.09
Noise Term						

log (σ_v^2)	-5.06***	0.34	-5.04***	0.35	-5.60***	0.32
Inefficiency Term (variance)						
intercept	-1.64***	0.09	-2.01***	0.10	-3.45***	0.27
log (*gc*)					-0.45***	0.10
pi					0.87***	0.22
hydro					0.001***	0.0002
reg					0.63***	0.22
cc					-0.24	0.17

Significance code : * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

Note: Underlined values are computed through the application of the homogeneity conditions.

The positive and significant coefficient of the *plf* variable indicates a positive correlation between reforms and the load factor of electricity generation portfolios in SSA. This finding can be explained by the increased share of CCGT in the generation capacity investments after reforms. These types of power plants are known to have higher firm capacity and for being less prone to adverse weather conditions. As at the end of 2017, over 84% of installed generation capacity in SSA was from these thermal sources. In addition to these favourable technological features, majority of the new investments were covered by power purchasing contracts which promotes the maximum utilization of power plants.

The coefficient of *losses* was, however, found to be negative. This indicates that reforms were negatively correlated with the rate of reduction in technical network losses. This finding is not surprising given the limited investments in network reinforcement and maintenance over the years, largely due to the lack of effective and sustainable business models for private investments. The concept of Independent Power Transmission is being explored but reservations about the institutional capacity of SSA countries to deliver such business models remain (World Bank, 2017a). As a result, electricity network infrastructures in SSA have become old and obsolete. Most countries in SSA are developing countries facing exponential demand growth due to increased economic activity, population growth and access expansion. With the increasing load in these dilapidated networks, the percentage of energy that is lost in transport often increases if the grid is not well-maintained and reinforced.

With respect to the reform steps, I find that the first order coefficients of *act*, *unb*, and *reg* are significant at 1% significance level and with the expected negative sign of the inputs' coefficients in an output distance function.

The significance of the coefficient of the *act* variable indicates the presence of an electricity law is a significant step for reform performance. This justifies the need for a legal basis for successful reforms.

The significance of the coefficient of *reg* also indicates the critical role of an autonomous authority in sector reforms, as an administrator of electricity tariffs, overseer of IPP negotiations and enforcer of third-party access, all of which are important considerations for prospective investors. However, I found a positive relationship between the presence of an electricity sector regulator and inefficiency, indicating that the presence of a regulator could be a source of inefficiency in reform performance. This finding suggests the presence of regulatory risks that could be disincentivizing investments and promoting technical efficiency in SSA electricity sectors (Eberhard et al., 2017).

The significance of the coefficient of *unb* indicates that vertical unbundling is a positive reform step for increasing investments and improving technical efficiency. This is a particularly interesting finding given that several SSA countries such as Liberia are contemplating whether to vertically unbundle their electricity sectors while others such as Zimbabwe are considering reintegrating their sectors. Of the 37 countries in our sample, seven countries had unbundled their electricity sectors as at the end of 2017, namely, Angola, Nigeria, Ghana, Kenya, Uganda, Zimbabwe, and Lesotho. These countries were also amongst the most extensive reformers in the region, with all having introduced at least two other reform steps. However, of these countries, Zimbabwe and Lesotho were the only unbundled electricity systems that featured in the top ten performers (details in Section 2. 5.1, Figure 2.4-2 with unbundled countries in yellow). Interestingly, these countries are members of the Southern African Power Pool (SAPP) which gives them access to a larger market. This finding suggests that the impacts of unbundling may be amplified when the country has access to and participates in a larger market.

We also find that *pi*, introduced in the model as a control variable has a negative and significant coefficient. This indicates that private ownership and management is a positive reform step for increasing efficient investments. However, this reform step is double edged as a positive correlation is also observed between its presence and inefficiency. During the period under observation, fifteen of the countries in the sample had has some form of private sector management and or ownership arrangement at some point (See Appendix 1). Of these countries, only Nigeria had undertaken full privatization (i.e., sold its generation and distribution assets to private entities while Uganda and Kenya had their utilities listed on their respective national security exchanges. Gabon and Cote d’ivoire had also divested parts of their national utilities. In addition, Uganda also appointed Umeme as the private distribution concessionaire. An interesting observation was that sustained private sector participation was concentrated in the Francophone African countries besides Nigeria, Uganda, and Kenya. In the remaining countries, private participation in the sector was temporal, usually between two to three years or were failed privatization attempts.

In several of these instances, cancellations of MSCs or concession contracts were due to deteriorated performance with the participation of the private sector. One of the reasons for this is that in several cases, data used in contracts were found to be inaccurate, with baseline performance benchmarks often worse than what was agreed in contracts. This makes the achievement of performance targets in contracts almost impossible in most instances. These discrepancies are often observed after contract signature when the private party has access to the books of the utilities. In some cases, contracts may be revised to reflect these changes but, in several others, contracts are abrogated. These revisions during periods of private sector participation (even if brief) often create an impression of deteriorated performance as observed in the positive correlation of *pi* with inefficiency.

In the assessment of the impact of institutional quality, I found a positive correlation between perceptions of Political Stability and Absence of Violence and Terrorism - *ps* and reform performance. This finding is as expected as electricity sector investments are usually immovable assets, making it particularly important to consider a safe environment in investment decision-making. Electricity sector assets have also historically been a target of civil unrest with notable examples including the destruction and looting of the Mount Coffee hydropower station in Liberia and the curtailed development of the Bumbuna hydropower station in Sierra Leone during periods of prolonged conflicts in both countries.

Contrary, the estimated coefficient of the Governance Effectiveness index, *ge,* is not significant. This indicates that perceptions of the quality of public and civil services, the degree of independence of these institutions from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies are not correlated with reform performance. This is also the case for the Regulatory Quality - *rq* dimension of the WGI. The insignificance of the coefficient of this variable indicates that perceptions about the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development is not a significant factor for reform performance.

We found the Control of Corruption variable – *cc* included as an inefficiency determinant to be insignificant. This finding shows that perceptions about the extent to which 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 has no relationship with reform performance.

Our general sense from these results is that perceptions about non-violent institutional aspects have no correlation with reform performance. This is largely because commercial interests are usually protected in contracts, and thus perceptions of non-violent institutional features may not be a determinant of investment decisions, especially as these contracts are usually enforced by international judicial systems.

We found the coefficient of installed generation capacity (as a proxy for system size) to be insignificant when introduced as a control variable but significant when introduced as a determinant of inefficiency. These results indicate that while there is no relationship between the size of electricity systems and reform performance, the size of an electricity sector is correlated with inefficiencies in reform performance. I also found that the size of the installed hydroelectric capacity, *hydro*, was positively correlated with reform performance and the inefficiency term, although the coefficient is negligible.

2.5.1 Reform Performance in sub-Saharan Africa

Reform performance in SSA from 2000 to 2017 has been irregular, with changes in trend coinciding with major global economic events. As shown in Figure 2.4-1, there is a dip in reform trends between 2002 and 2003 which can be explained as a learning curve effect. However, from 2003 to 2009, a slow but steady improvement in performance is observed from an average performance score of 74% to a peak of 78% in 2009. Performance begins to fall after 2009 and this can be explained by the 2007/2008 financial crises during which access to capital was limited, severely constraining investments in electricity infrastructure globally and curtailing ongoing projects (IEA et al., 2009). With investments a main indicator of performance in this study, it is unsurprising that the adverse effects of the crises can be observed in this performance trend. However, in 2012/2013, the deterioration in performance seemed to have been abated and this change is observed to coincide with the US shale revolution in 2012/2013. The increase production of US tight oil and gas through fracking created a surplus of crude oil on the international market which led to a fall in crude oil prices. This bolstered global economic growth (except for oil exporting countries) and ameliorated the effects of the financial crisis.

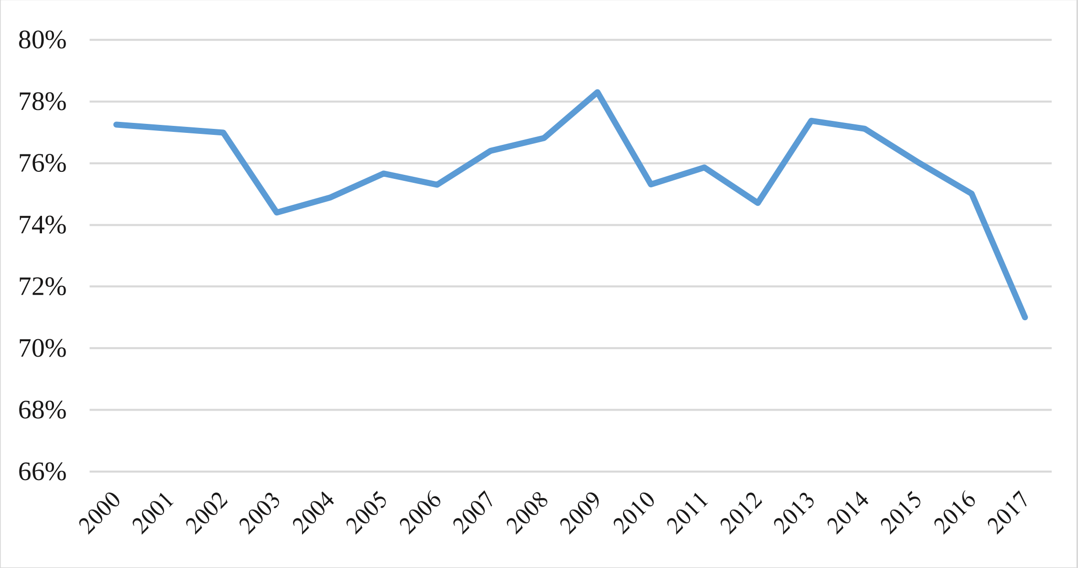

Figure 0-1: Electricity Sector Reform Performance Trend in SSA from 2000 to 2017

In addition to the annual performance scores estimated, I also estimated the average performance scores for each country from 2000 to 2017 (See figure 2.4-2 and Appendix 1.4). These scores indicate the country-level efficiency of transforming reforms into the observed sector performance outcomes. In this, Gabon emerged as the most efficient reformer with an average score of 93% followed by Cote d'ivoire, South Africa, and Senegal in second place and Zimbabwe in third place. There are no doubt important lessons in the experiences of all countries in the sample but for the purpose of this exercise, I focus my discussion on the top four most efficient reformers mentioned above.

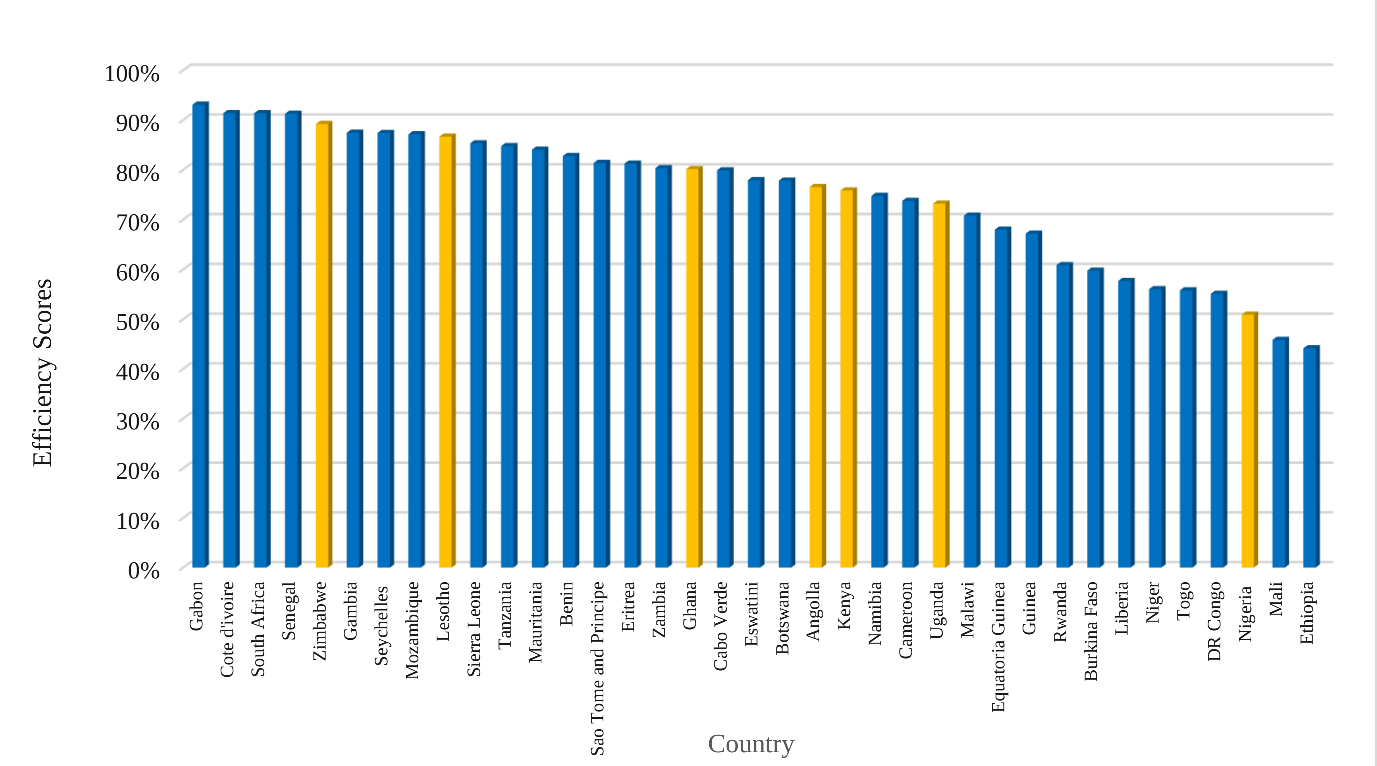

Figure 0-2: Average efficiency scores of SSA countries (2000-2017).

Gabon is among the earliest reformers in SSA having given its vertically integrated utility – the Société d'Electricité et d'Eaux du Gabon (SEEG) out as a concession as early as 1995. The concession aimed at leveraging the private sector to instil commercial discipline and improve the operational performance of SEEG. The Concession consortium also acquired 51 percent of SEEG and made an Initial Public Offering (IPO) for the remaining 44 percent of the company's shares with an exclusive offer of five percent to SEEG employees. While the Concessionaire was responsible for managing the generation infrastructures, investments in new generation capacity remained with the state. As seen from figure 2.4-3, there is a gradual decline in installed generation capacity per capita over the period under observation, but there are noticeable improvements in plant load factor while changes in technical losses remain negligible over the years.

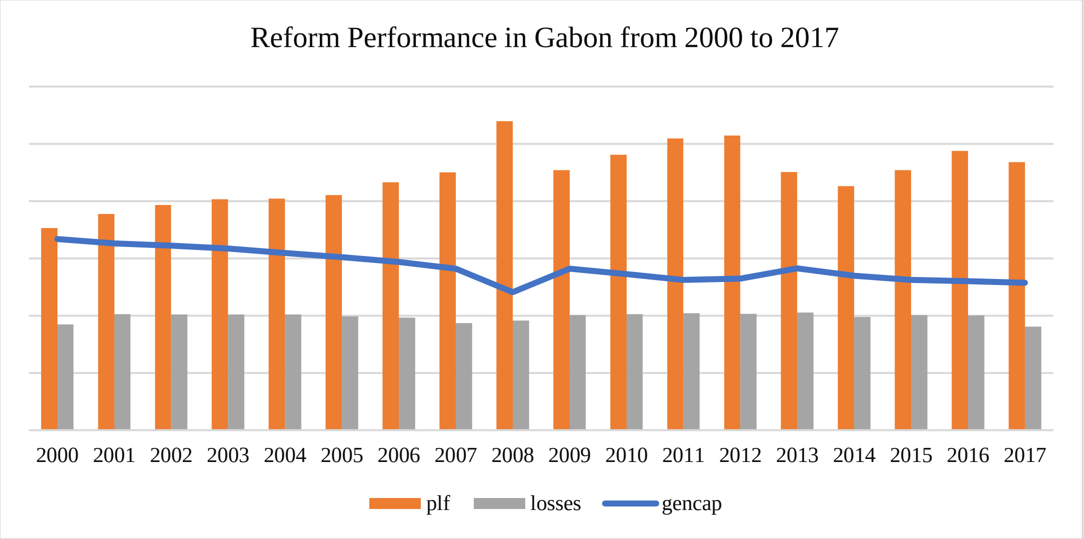

Figure 0-3: Evolution of plant load factor (in percent), technical network losses (in percent) and installed generation capacity per capita (in kilowatt) in Gabon

Côte d'Ivoire hosted the first IPP project in the region in 1994, the 210MW Compagnie Ivorienne de Production d'Électricité (CIPREL) owned by the French Eranove group. The success of CIPREL stimulated interests in the second IPP, the 330MW Azito gas-fired plant which came online in 2000 and was the largest IPP project in West Africa at the time. Currently, Côte d'Ivoire is a net exporter of electricity to Benin, Burkina Faso, Ghana, and Togo. In addition, the vertically-integrated Compagnie Ivoirienne d'Électricité (CIE) was given out as a concession to Eranove as far back as 1990. CIE was also divested, with Finagestion, a subsidiary of Emerging Capital Partners owning 54% of the total shares, and the State of Côte d'Ivoire owning 15%, private Ivorian investors owning 26%, and the employee pension fund of CIE owning the remaining 5%. Arguably, the involvement of the private sector in generation promoted efficient technology choices and optimal utilization of power plants as can be seen from the trend in load factor and installed generation capacity which has remained relatively stable over the period. See figure 2.4-4.

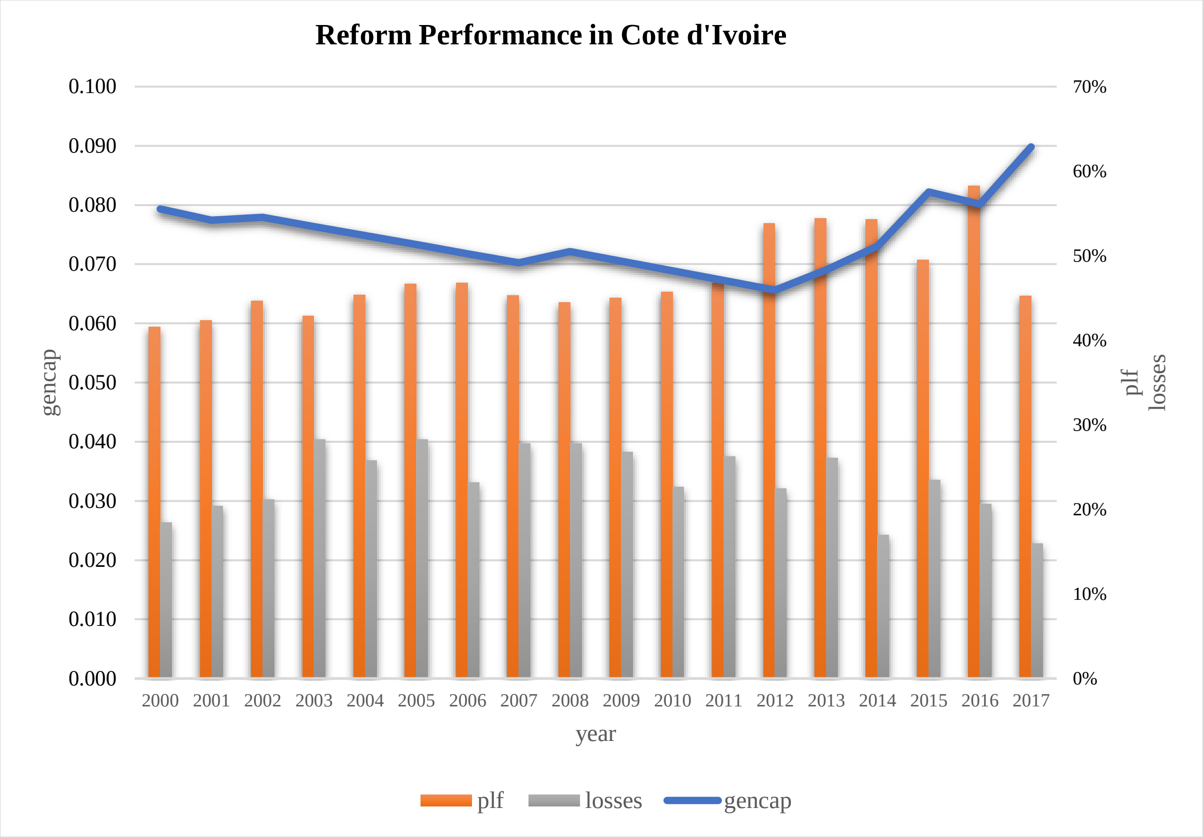

Figure 0-4: Evolution of plant load factor (in percent), technical network losses (in percent) and installed generation capacity per capita (in kilowatt) in Cote d'Ivoire

Senegal shares a similar experience with Cote d'ivoire with respect to its earlier experience with IPPs, having commissioned its first IPP Plant, the Gti Dakar as early as in 2000. The state-owned vertically-integrated utility - SENELEC owns about half of the generation capacity, with the remaining capacity owned by IPPs. Thus, it is unsurprising to see a steady increase in installed generation capacity per capita during the period under observation. While the load factor of the generation portfolio never reached the levels of the early 2000s, a steady improvement is observed from the mid-2000s onwards. SENELEC remains publicly-owned and managed. However, the Government has a unique arrangement with its staff by means of a performance contract since 2012. The agreement includes an incentive scheme of bonuses and sanctions which has been reported to have led to improvements in operational performance and the technical efficiency.

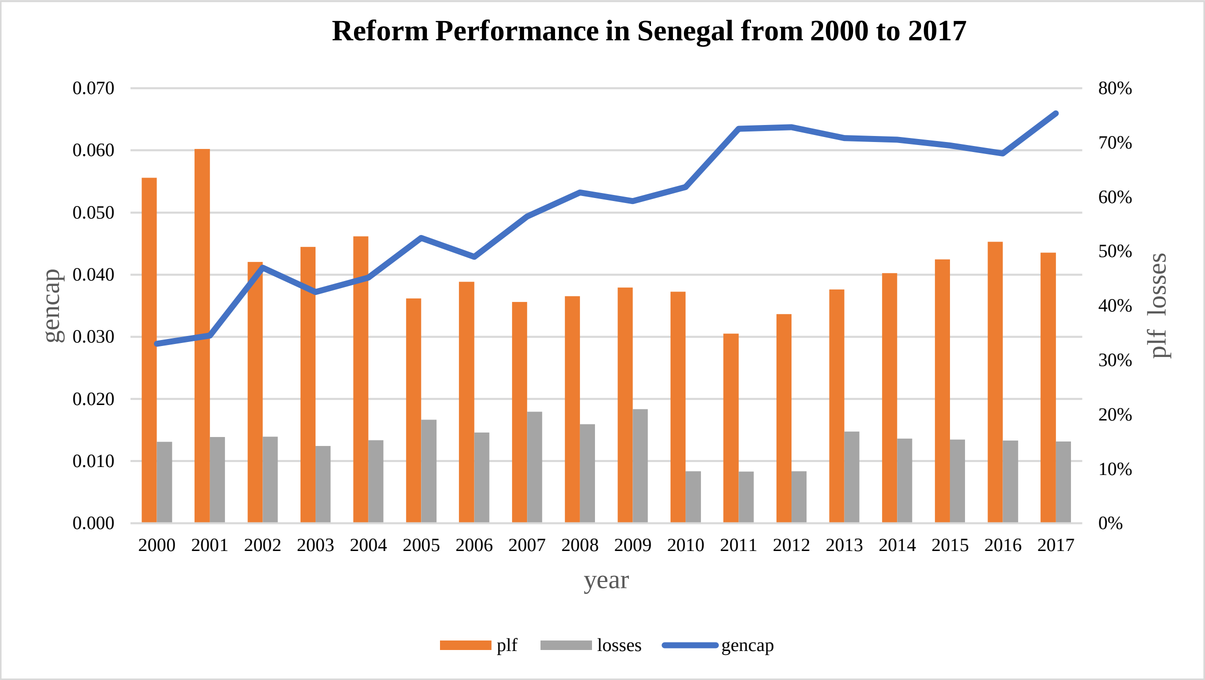

Figure 0-5: Evolution of plant load factor (in percent), technical network losses (in percent) and installed generation capacity per capita (in kilowatt) in Senegal

What these three countries share is a Francophone colonial heritage and corresponding institutional structures that are favourable for regulation by contracts. These institutional assets make engagements with the private sector easier and the liberalization process more sustainable.

South Africa is unsurprisingly in the top performing countries, being home to over 50% of the installed generation capacity in SSA. The structure of the South African electricity sector is especially unique, remaining vertically-integrated despite being the largest electricity system in the region. The fully state-owned utility, Eskom, holds 91% of the country's gross generation capacity with the remaining held by 137 municipal power companies (1.77%) and IPPs (7.21%). It has 30 operational power stations with a nominal generation capacity of 44,172MW, comprising coal (85.1%), gas (5.6%), hydro (4.7%), nuclear (4.3%) and wind (0.2%) power plants.

Eskom owns, operates, and maintains 95% of the national transmission network and shares the distribution network with 187 licensed municipal distributors. Eskom was converted from a statutory body into a public company - Eskom Holdings Limited in July 2002. It is the only country of the four top-performers that initiated reforms very late as it relied on public funds for sector investments. This was made possible by its Upper-Middle-Income economy status. At the earlier stages of reforms, South Africa was one of the few countries in SSA that had excess generation capacity but continued to investment in new generation capacity. Investments in the generation were also complemented by massive investments in the networks in the forms of grid reinforcements and extension, the result of an ambitious electrification programme by the new post-apartheid Government.

South Africa is one of the few countries in SSA that had the means as well the zeal to invest in the electricity sector without private capital. It is therefore unsurprising that it has one of the highest plant load factors, highest per capita generation and lowest technical network losses which never exceeded 10 percent during the period under observation. See figure 2.4-6. Currently, it is the largest exporter of power within the SAPP, trading electricity with Botswana, Lesotho, Mozambique, Namibia, Eswatini, Zambia and Zimbabwe. However, over the last few years, there have been concerns about tightening spare capacity which could compromise future trade.

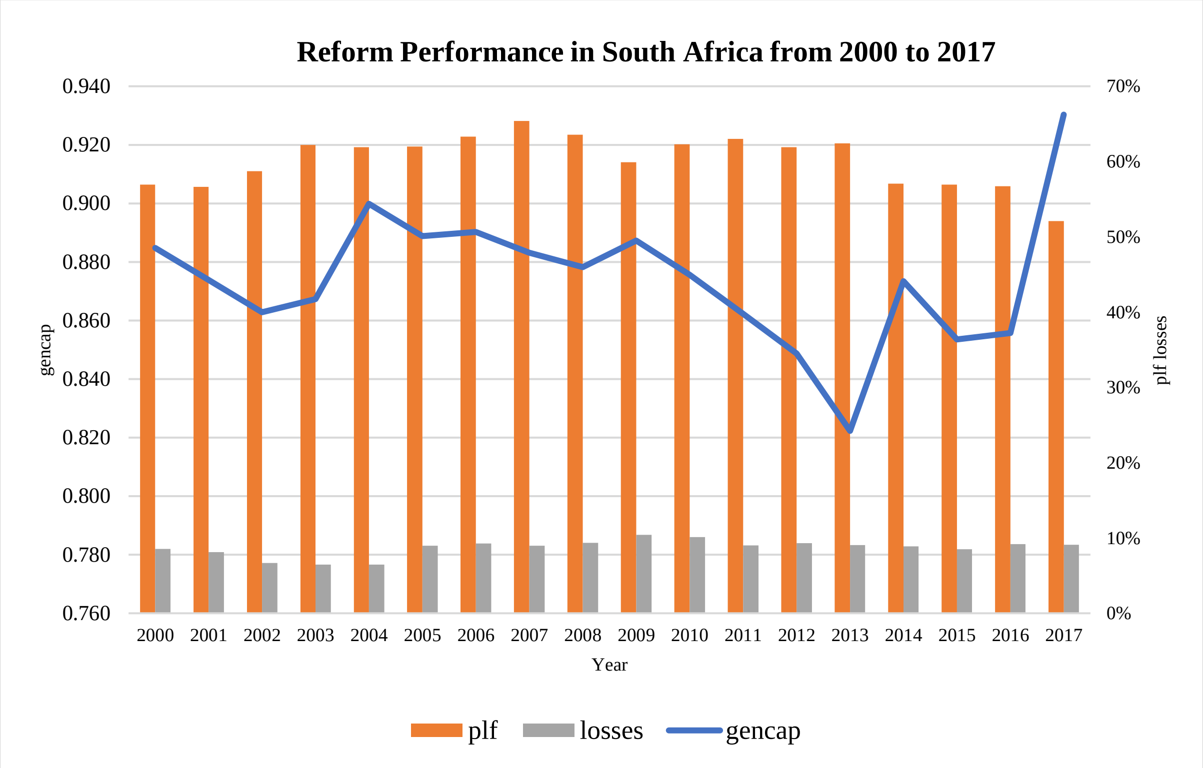

Figure 0-6 : Evolution of plant load factor (in percent), technical network losses (in percent) and installed generation capacity per capita (in kilowatt) in South Africa.

2.6. Conclusion And Policy Implications

In this study, I assessed the performance of electricity sector reforms for a set of 37 SSA countries from 2000 to 2017. A multi-input multi-output distance function was used to define a performance frontier comprising three indicators, i.e., net installed generation capacity per capita, plant load factor, and level of technical network losses. This performance frontier was modelled as a function of some reform steps including the enactment of an electricity law, vertical unbundling of the electricity supply industry, and the establishment of an electricity sector regulator. Private participation in the ownership and management of electricity assets was included as a control variable. The presence of a sector regulator and private participation were also included as inefficiency determinants.

In order to understand the impact of institutional quality on reform performance, I included four dimensions of the WGI, namely, perceptions of political stability and absence of violence and terrorism, control of corruption, regulatory quality, and government effectiveness as measures of institutional quality. The level of installed hydroelectric capacity in the generation portfolio was also included as a control variable and as a determinant of inefficiency to understand the effects of hydrology on reform performance. Lastly, I included the installed generation capacity (as a proxy for the size of the electricity sector) in the model as a control variable and determinant of inefficiency.

The results show that reforms are positively correlated with installed generation capacity per capita, the rate of increase of plant load factor and negatively correlated with reduction in technical network losses. I also found that the presence of an electricity law, vertical unbundling of electricity sector and the presence of an electricity sector regulator were significant inputs to reform performance. Private participation introduced as a control variable was also found to be positively correlated with reform performance. However, private participation and the presence of the sector regulator were also sources of inefficiency in the model with inefficiency increasing with the implementation of these reform steps.

I found perceptions about political stability and absence of terrorism and violence was positively correlated with reform performance. However, perceptions about regulatory quality and governance effectiveness had no bearing with reform performance. Also, perceptions of corruption were not a source of inefficiency in the model. The effect of hydrology on reform performance was small but significant both as a control variable and as a determinant of inefficiency. Finally, I found a negative relationship between the size of an electricity sector and inefficiency, indicating that larger electricity systems are more efficient reformers than smaller ones.

I conclude that the structure of a desirable reform model in SSA for maximum technical efficiency improvements and investment involves a vertically unbundled electricity sector with an independent regulator. This framework should be legally enshrined in an electricity law, with private participation in the operations and management of electricity assets where preferred. However, the positive outcomes of reforms may go hand in hand with an increase in technical network losses. Hence, emphasis should be put on decoupling these losses from generation capacity and plant load factor.

3. Electricity Access in Sub-Saharan Africa: *A Stochastic Frontier Analysis of Determinants and Performance*

3.1. Introduction

Access to electricity is a critical prerequisite for inclusive growth across age, gender, and geography in the modern world (Khandker et al., 2013; Khandker et al., 2012; Barnes, 2007; Ahlborg, 2012; World Bank, 2017b). The evidence from developing and transition economies indicate that access to affordable, reliable, and secure energy services has resulted in substantial socio-economic benefits related to industrial growth, education, health, and security (Kanagawa and Nakata, 2008; Karekezi and Kimani, 2004; Spalding-Fecher, 2005; Pachauri et al., 2013; Lucas et al., 2017). However, a significant proportion of the global population is still without access to electricity, and an overwhelming percentage of this deficit is in sub-Saharan Africa (SSA). Specifically, about 70 percent of the global electricity access deficit, which translates into about 548 million people is in this region of the world (World Bank, 2020a).

Given the importance of modern energy services to economic growth and human development, electricity for all has become a national, regional, and global priority (Scott et al., 2014; United Nations, 2015; AfDB, 2016). In 2015, the Sustainable Development Goal number 7 (SDG-7) committed to universal access to modern energy services including electricity by 2030. This initiative has accelerated the pace of electrification globally, and in SSA, the percentage of people with access to electricity was estimated to have increased from 44 percent in 2017 to about 47 percent in 2018 (World Bank, 2019b). However, it is projected that even if this momentum is sustained, universal access by 2030 is not assured, and more people could in fact be without access to electricity in 2030 than there are today.

This has made it imperative to boost supply-side efforts, by accelerating the extension of transmission lines and distribution wires, while providing off-grid and standalone solutions where grid extension is not a viable solution. It has also become evident that, we need to remove demand-side barriers which was found to account for about two-fifths of the electricity access gap in a sample of SSA countries (Blimpo and Postepska, 2018). In fact, the study found that about 57 percent of people living near an electricity grid remained unconnected, noting that if all households within the range of an electrical grid were connected, electricity access rates would be well over 60 percent in the sub-region and nearly double the current rates in most countries (Blimpo and Cosgrove-Davis, 2019; Blimpo and Postepska, 2018).

Electrification is generally pursued by the public sector as a standalone social programme while electricity service is delivered by power utilities based on commercial principles. The separation of electrification from mainstream operational activities of the power sector was informed by decades of market-based reforms which aimed at improving the commercial viability of the electricity sector and facilitating efficient investments. Reforms did not explicitly pursue access expansion as the application of commercial principles to electrification would preclude poor populations from accessing the service and an insistence on making it an operational objective undermined the fundamental principles of the market-based reform agenda. Thus, while reforms advocated for the withdrawal of the public sector from electricity sector operations, it conferred on it the responsibility for access expansion.

Despite this structural separation of mandates, electricity sector operations and access expansion remain profoundly connected, with operational performance having major implications for electrification and vice versa. One of the expected outcomes of reforms was to relieve the public sector of the financial burden of the electricity sector to make more resources available for the provision of other pressing social services such as access to electricity. Also, investments in generation and network capacity as a result of reforms would support access programs. Thus, while reforms did not explicitly pursue access expansion, the various reform steps, and the performance of the programme has major implications for electrification.

Few studies have explored the connection between reforms and access and how it could be leveraged for better outcomes in the sector. In this study, I investigate the determinants of electricity access performance from the perspective of sector reforms and within the broader demographic, macroeconomic and institutional contexts. I use a production function and a Stochastic Frontier Analysis (SFA) approach to estimate a frontier function for electricity access performance using a dataset for 46 countries in SSA from 2000 to 2017. I consider connection rates as the dependent variable, and this is modelled as a function of some technical efficiency indicators which are the products of successful reforms, some reform steps, and some institutional, demographic, and macroeconomic variables. To the best of my knowledge, this is one of the earliest panel data studies on electricity access performance in SSA exploring the relationship between access outcomes and broader sector reforms and one of the first studies to explicitly include demand-side variables in the modelling of electricity access.

The remainder of the study is organised as follows. Section 2 is the literature review which presents the history of electrification[20] in SSA, its key determinants, and the role of reforms in this.[21] Section 3 presents the methodological approach and data utilised for the study. Section 4 presents the results. Section 5 concludes the study with recommendations for policy.

3.2. Literature Review

This section presents a commentary on the history of and rationale for electrification in SSA since the colonial era. It presents various definitions of electricity access, its implications for the 2030 universal

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[20] I use electrification and electricity access interchangeably in this study.

[21] Uptake and connections are used interchangeably as is access and electrification.

access targets, energy poverty, and the sustainability of electrification outcomes. Key supply-side factors of access pertaining to financing, geography, demography, operational performance, and the role of sector reforms and institutional quality are discussed. Finally, demand-side aspects of electricity access are examined.

3.2.1. History of Electrification in Sub-Saharan Africa

During the colonial era, electricity was regarded as a symbol of modernity as well as an important factor of production. Electrification patterns generally reflected the economic interests of colonisers, with electricity typically provided on plantations, industrial complexes, and mining centres (Showers, 2011). Household access to electricity was not considered a priority (Bernard, 2012).

As in Europe and North America, electrification in SSA began with small-scale isolated generators supplying plantations, industries, and transit systems with power, and municipalities with lighting (Showers, 2011). These generators were typically fuelled by wood in East and Central Africa, coal in Southern Africa and imported oil in West Africa (Showers, 2011). The idea of large-scale electricity infrastructures in SSA emerged after World War II when European reconstruction programmes and the associated economic boom created a high demand for metals, especially aluminium, which was abundant in SSA (Showers, 2011). The development of these resources was highly energy-intensive and in most of these countries, energy resources were not developed. Thus, large-scale electricity infrastructures, especially hydropower were developed to support the processing of these metals needed for the reconstruction of Europe (Showers, 2011). These metal processing plants were often sited close to the source of power to avoid the exorbitant costs of long transmission and distribution lines. Industrial complexes and duty-free zones subsequently began to form around these sites and with time they emerged into major centres of economic activities and opportunities (Showers, 2009). Thus, an impression began to form that access to electricity is key to economic growth.

From the mid-1950s to 1975, colonisation of most African countries ended, and for new independent states, electricity was viewed as a critical infrastructure for economic growth and development. Large hydropower projects became a symbol of liberation and economic transformation, and as symbols, they were contested politically, especially in countries where minority rule continued even after the colonial era (Showers, 1998). Newly independent SSA governments embarked on extensive electrification of their countries with the hope of replicating observed patterns of economic growth which seemingly correlated with patterns of electrification. Household access, which was hitherto concentrated in areas habited by colonisers became the representation of new-found freedoms and the modern economy new governments sought to develop.

With time, electricity became a major tool for political patronage as countries transitioned into democratic governments. Electricity sectors became heavily subsidised, and operational inefficiencies became commonplace in utilities across the region (Komives et al., 2007; Cook et al., 2015; Williams and Ghanadan, 2006). This began to manifest in poor service quality, high technical and commercial losses, price-cost margins, and capacity shortages as utilities struggled with unfamiliarly large customer bases (Cook et al., 2015; Williams and Ghanadan, 2006).[22] With these developments, the appeal of electricity as a public service began to diminish, and a new conceptualisation of electricity as a commodity emerged. This informed extensive market-based reforms in the sector with the intention of bringing business rigour into the otherwise lackadaisical management of utilities. However, the responsibility of access expansion remained with the state, and electrification programmes were assigned to designated electrification agencies which run parallel to the reforms.

In 2000, the launch of the Millennium Development Goals (MDGs) highlighted the role of electricity in poverty reduction. While universal access to electricity was not an explicit goal, it was indicated to be essential in achieving the MDGs related to poverty reduction, health, education, gender equality and environmental sustainability. This period witnessed a stronger involvement of international development partners in electrification endeavours in SSA, and a renewed commitment to ensure universal access by 2030. There was some experimentation with bundling electrification with other social programmes as awareness of the demand-side aspects had begun to form (Bernard, 2012). However, as access to electricity was not an explicit MDG,[23] there was no framework to track its progress or measure its outcomes.

In 2011, the United Nations launched the Sustainable Development Goals (SDGs), which was effectively a consolidation of the MDGs, and the lessons learnt (Kumar et al., 2016). The SDGs in its Goal 7 (SDG-7) committed to: (a) ensuring universal access to affordable, reliable, and modern energy services; (b) increasing substantially the share of renewable energy in the global energy mix; and (c) doubling the global

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[22] In the colonial era, national utilities served a few industrial areas with a few concentrated consumers. As the number of household consumers increased, the customer base began to decentralize, and several operational challenges began to emerge with major political, economic, and social implications.

[23] One of the reasons why universal access to electricity was not considered as an MDG was that there was still no consensus on whether energy was a means or an end (goal). There were also some complexities surrounding the implications of access expansion for climate change which needed to be navigated tactfully.

rate of improvement in energy efficiency by 2030.[24] For the first time, there was an explicit time-bound global commitment to universal access to electricity, and this imposed the much-needed sense of urgency.

The advent of the SDGs has reshaped in a major way how electricity access was conceptualised over the years, raising fundamental questions about how electricity access is defined, measured, and tracked. Traditional definitions of access have come under major scrutiny for its limited representation of the electricity access situation. For instance, definitions which focused on the physical connection of households to an electricity network or the proximity of households to electricity networks were criticised for neglecting non-residential access (i.e., access by businesses and community infrastructures), and its failure to capture reliability, safety, and legality attributes (Sedai et al., 2021; World Bank, 2017). It was also criticised for its exclusion of private electrification solutions such as the use of diesel gensets and distributed generation solutions such as Solar Home Systems (SHS).

The World Bank's Multi-Tier Framework (MTF) has attempted to address the flaws of these traditional definitions of access in a radical departure from the conventional binary metrics discussed above. Under the MTF, electricity access is defined as "the ability to avail energy that is adequate, available when needed, reliable, of good quality, convenient, affordable, legal, healthy and safe for all required energy services" (Bhatia and Angelou, 2015 page 4). Based on this, electricity access is measured across a spectrum of five tiers, with each tier involving progressively higher demands (and supply) and hours of availability (see Figure 3.2-1).

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[24] The SDGs also included 2030 targets to "(i) Enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology and (ii) Expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing states, and land-locked developing countries, in accordance with their respective programmes of support" (UNDP, 2020)

Tier 0	Tier 1	Tier 2
Electricity is not available or is available for less than 4 hours per day (or less than 1 hour per evening). Households cope with the situation by using candles, kerosene lamps, or dry-cell-battery-powered devices (flashlight or radio).	At least 4 hours of electricity per day is available (including at least 1 hour per evening), and capacity is sufficient to power task lighting and phone charging or a radio. Sources that can be used to meet these requirements include a SLS, a solar home system (SHS), a minigrid (a small-scale and isolated distribution network that provides electricity to local communities or a group of households), and the national grid.	At least 4 hours of electricity per day is available (including at least 2 hours per evening), and capacity is sufficient to power low-load appliances—such as multiple lights, a television, or a fan (see table 1)—as needed during that time. Sources that can be used to meet these requirements include rechargeable batteries, an SHS, a mini-grid, and the national grid.

Tier 3	Tier 4	Tier 5
At least 8 hours of electricity per day is available (including at least 3 hours per evening), and capacity is sufficient to power medium-load appliances—such as a refrigerator, freezer, food processor, water pump, rice cooker, or air cooler (see table 1)—as needed during that time. In addition, the household can afford a basic consumption package of 365 kWh per year. Sources that can be used to meet these requirements include an SHS, a generator, a mini-grid, and the national grid.	At least 16 hours of electricity per day is available (including 4 hours per evening), and capacity is sufficient to power high-load appliances—such as a washing machine, iron, hair dryer, toaster, and microwave (see table 1)—as needed during that time. There are no frequent or long unscheduled interruptions, and the supply is safe. The grid connection is legal, and there are no voltage issues. Sources that can be used to meet these requirements include diesel-based mini-grids and the national grid.	At least 23 hours of electricity per day is available (including 4 hours per evening), and capacity is sufficient to power very high- load appliances—such as an air conditioner, space heater, vacuum cleaner, or electric cooker (see table 1)—as needed during that time. The most likely source

Figure 3.2-1 The Multi-Tier Framework

Source: (Bhatia and Angelou, 2015 page 6)

This categorisation has enabled a tactical redefinition of the electricity access situation and permitted a strategic rollout of programmes that reflects the heterogeneous needs of various consumer groups. It draws attention to the large number of people who are physically connected to sources of electricity but receive insufficient and unreliable supply (Odarno et al., 2017; Bhatia and Angelou, 2015). It also accentuates the dual demand and supply features of electricity access and the need for a policy and academic conceptualisation of electricity access beyond connections to encompass the actual use of the service.

However, it must be noted that available time series estimates of electricity access do not reflect all aspects of the MTF due to data limitations (World Bank 2017b).

The MTF has been the basis for attuning investment strategies to demand profiles, and this has major implications for energy poverty and the sustainability of electrification outcomes. The MTF has made electrification an iterative process which needs to evolve with changing demand profiles. This implies that in the absence of an amenable mechanism to respond to changing demand needs, populations on lower-tiered access levels can fall back into energy poverty overtime. This is especially true for lower-tiered access solutions typically referred to as "pre-electrification solutions", which are nonetheless included in the estimation of electrification rates.

As at the end of 2018, tier 1 solutions (typically comprising SHS and Solar Lanterns) were providing basic electricity services to 136 million people globally. In SSA countries like Kenya, Rwanda, Somalia, and Uganda, over 10 percent of official estimates of electricity access was Tier 1 access (IRENA, 2020). It is important that electrification tracking is unequivocal about what level of access is being reported to avoid locking the poorest populations into perpetual energy poverty.

3.2.2. Supply-Side Determinants of Electricity Access

According to the IEA (2016), grid extension was the technical solution for 97% of people who gained access to electricity from 2000 to 2016 and would likely remain the most favourable electrification option for about 40 percent of remaining households.[25] Grid extension, however, requires adequate generation, transmission, and distribution capacity to avoid disruptions to existing operations (Bekker et al., 2008; Shrestha et al., 2004; IEA, 2017; Cook, 2011). Most SSA countries typically have limited generation capacity and network bottlenecks, and additional capacity and network reinforcements are typically required for the system to be effectively extended.

Eberhard and Shkaratan (2012) indicates that installed generation capacity will need to grow by more than 10% annually to meet suppressed demand, keep pace with projected economic growth and support the rollout of further electrification programmes in line with poverty alleviation plans. The network infrastructure would also need to be extended, given that the combined length of transmission lines in 38 countries in Africa is estimated at about 112,196 km, which is lower than that of Brazil of 125,640 km (World Bank, 2017b). The World Bank estimates that reaching universal access globally on Tier 5 of the MTF categorisation (full 24x7 grid power) would require investments of about $50 billion annually up to 2030 (Bhatia and Angelou, 2015). However, there is a significant drop in costs when using the bottom-up

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[25] These estimates are based on the 2030 universal access target.

approach of the multi-tier framework. For instance, reaching universal access on Tier 1 of the MTF (enough to light a few light bulbs and charge a mobile phone) would require investments of $1.5 billion annually up to 2030. These cost considerations as well as the unfavourable geographical terrains and dispersed nature of the remaining unelectrified populations have made a strong case for off-grid solutions for the remaining 60 percent of the population (Odarno et al., 2016).

Whichever way, there is limited space in the budgets of SSA countries to finance the required investments on any tier. Unfavourable market perceptions[26] about SSA economies undermine the ability of countries to mobilise adequate financial resources at competitive rates from the capital markets. Brew-Hammond (2010) notes the need for a strategic mobilisation of the whole range of financing solution for electrification programmes including public sector resources in the form of budget allocations, surcharges, and levies, among others, along with private sector capital in the form of equity and debt, both locally and internationally (Brew-Hammond, 2010).

Generally, wealthier countries, especially those with natural resources have a better capacity to make these investments and would be incentivised to do so as access expansion is considered a good way to distribute natural resources equitably (Fuss et al., 2016; World Bank, 2017b). Blimpo and Cosgrove-Davies (2019) explain that access provision is a time-consistent way of saving or investing resource rents for future generations as electricity access is a long-term investment. However, countries such as Mongolia, China[27] and Yemen attained high connection rates at low national income levels whereas countries like Namibia, Gabon, and Botswana had lower electrification rates at relatively higher income levels (van Ruijven et al., 2012). More so, evidence from resource curse studies indicate that inequality is perpetuated in all aspects of economies with substantial natural resources, and this is sometimes manifested in disparities in access

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[26] Calderón and Zeufack (2020) notes that while the level of indebtedness in SSA has reduced, the risk profile of public debt has increased sharply with the declining share of concessional public debt and an increase in debt owed to private creditors and non-Paris Club bilateral creditors. The resulting reconfiguration of public debt has led to a significant increase in the region's debt service, which in combination with higher risk debt profile might lower the threshold for debt distress in the region.

[27] China had more than 98 percent electricity access rates in 2000 when 56% of its population lived in poverty (Ying et al., 2006; World Bank, 2017).

to basic infrastructures like electricity. This is observable in several resource rich SSA countries where access rates remain low and concentrated in urban centres.[28]

Generally, it is not only the lack of financial resources that hinders economic development in developing economies such as those in SSA, but the low quality of institutions (Acemoglu et al., 2002; Acemoglu, 2005; Acemoglu and Johnson, 2005, 2008; Cubbin and Stern, 2006). Good governance and strong institutions have been indicated to be critical determinants of infrastructural service delivery and management (Bazilian et al., 2011; Nanka-Bruce, 2010; Acemoglu and Robinson, 2008; Karekezi and Kimani, 2002). This is also true for access expansion, with the literature on electrification noting the effects of weak organisational structures, governance ineffectiveness, and corruption in electricity access provision (Ahlborg and Hammar, 2014; Karekezi and Majoro, 2002; Rothstein and Teorell, 2012; Karekezi and Kimani, 2002; Zomers, 2003).

The effects of various governance indicators on electrification have been explored in several studies, but the cross-cutting theme in electrification success stories is the consistent reference to government commitment to electrification programmes. As explained by Onyeji et al. (2012), some governments have been more successful in their electrification endeavours because of their prioritisation of the programme. For instance, in post-apartheid South Africa, more people were connected to the electricity grid in seven years than they were in a hundred years, raising electrification levels from about 30% to an estimated 70% by 1998 (Becker et al., 2008). Davidson and Mwakasonda (2004) explain that the political dynamics at the time propelled the new independent government to commit to very ambitious electrification targets, which it pursued aggressively. Onyeji et al. (2012) further notes that in Morocco, Tunisia, and Vietnam, electricity rates were very high despite scoring very low on governance and other development-related indicators.[29]

However, it is unclear what shapes this commitment incentive. Some studies have tried to explain this with systems of government. For instance, socialist governments[30] have been indicated to have a stronger

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[28] Natural resource rents accounted for approximately 9.3% of GDP on the average in 2018 with significant variations across countries.

[29] Morocco and Tunisia transitioned from access rates below 3% in 1996 to above 96% in 2009. Vietnam increased electricity access rates from 50.7% in 1996 to 97.6% in 2009 (World Bank, 2017b).

[30] Note that there are no official criteria for being named a socialist state. It is usually self-identified and includes nations that claim to be socialist or have constitutions stating that they are based on socialism, even if they do not

inclination for faster access expansion. Also, autocratic governments may be swayed to pacify their restive citizens with infrastructures such as electricity while democratic governments in a bid for re-election may accelerate access expansion, especially as elections approach. Despite the differences in motivations, it is arguable that the commitment of governments to provide access to infrastructures such as electricity is influenced by the extent to which they are accountable to their populace.

3.2.3. Reforms and Access

While market-based reforms can be used to address various economic efficiency challenges in the electricity sector, its focus in the first wave of reforms was on promoting investments, improving productive efficiency, and removing subsidies in the sector. It had no explicit provision for poverty-related concerns such as electricity access (Joskow, 1998). Rather, access expansion, especially rural electrification, was pursued as publicly funded social programmes while utilities provided the service in urban centres where there was a stronger business case (Estache et al., 2002; Carvalho et al., 2015). In some cases, there were some experimentations with tying network expansion to privatisation and concession agreements, but the outcomes were mixed (Victor, 2005).[31]

Despite no theoretical basis to expect a relationship between sector reforms and access, some studies have found such a connection. For instance, competition and increased regulatory governance during reforms were indicated to have enhanced service penetration in some developing countries (Zhang et al., 2008). Evidence from Latin American countries showed that private sector investments, improvements in regulatory quality and overall institutional reforms improved electricity coverage in the region (Balza et al., 2013; Kozulj and Di Sbroiavacca, 2004). Specifically, the post-reform electrification rates in Argentina, Peru, and El Salvador increased by about 4%, 34%, and 10% respectively from the respective pre-reform rates (Balza et al., 2013). In Chile, the number of households without electricity access decreased from 62% in 1982 to 14% in 2002 following reforms (Pollitt, 2004). However, this positive correlation between reforms and access rates have not held in other cases. For instance, Sen and Jamasb (2012) found a decline in electricity access rates in Indian states after reforms similar to findings by Sihag et al. (2004). The study explains that greater transparency after reforms might have revealed the actual electrification levels that may have been previously overestimated (Sen and Jamasb, 2012).

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follow the economic or political systems associated with socialism. Countries that appear to follow socialism are not designated as socialist unless the nation explicitly states so, regardless of how it is viewed by outsiders.

[31] Mini grid and off-grid solutions are providing avenues for private solutions in electrification.

A World Bank (2005) study examined the impact of reforms on electricity access in six SSA countries. In Tanzania and Uganda, there was no substantial improvements in access following reforms and access rates remained low among the rural population. The study explains that the two-year management service contract in Tanzania (which was the main reform step considered) was an interim measure toward subsequent privatisation. It was thus intended to instil commercial discipline, with no specific arrangements for access (World Bank, 2005). In Namibia, on the other hand, the private company Northern Electricity proactively invested in new electricity connections which resulted in increased access rates. The general finding of the study was that reforms do not necessarily accelerate access, especially to the poor, although systematic information to support this was lacking (Victor, 2005). The study concluded that electrification programmes in SSA would be more successful if they are driven by clear national targets, anchored in a firm financial and operational footing, and monitored by competent and independent institutions (World Bank, 2005).

A review of studies exploring the reform-access nexus revealed some important observations. The choice of reform indicators appeared to be critical in the results observed. In studies where indicators of intermediate reform outcomes such as competition and regulation are considered as explanatory variables, a positive relationship between reforms and electrification outcomes is often observed (Sen et al., 2017; Zhang et al., 2008; Balza et al., 2013; Kozulj and Di Sbroiavacca, 2004). Similarly, the presence of IPPs which is sometimes considered as a reform step is conceivably a product of successful sector liberalisation. On the other hand, in studies that reform steps to liberalise the sector such as the presence of an electricity law, unbundling, privatisation, the presence of a sector regulator are considered as explanatory variables of access, the result is mixed with no significant relationship observed in most and some correlation observed in others.

In this study, I test this theory by including reform steps towards sector liberalisation and indicators of reform performance (i.e., investments and technical efficiency) as explanatory variables of the rate of electricity access.

3.2.4. Demand-Side Determinants of Electricity Access

Demand-side challenges to electricity access are not new. However, as it is generally the poorest groups that have the least access to basic infrastructures such as electricity, demand-side issues have become more prominent as we approach universal access. Blimpo and Cosgrove-Davies (2019) conceptualises the demand-side aspects of electricity access with consumer theory, with demand decisions indicated to be a function of prices, income, and expected benefits of electricity uptake. By this, consumer decisions to connect and use electricity is indicated to be influenced by the affordability of the service, which is a function of income and prices (connection costs and monthly bills), and the perceived value of use. This is particularly relevant in SSA where about 68 percent of the population live below the poverty headcount ratio of $3.20 a day (World Bank, 2020a). Blimpo and Postepska (2018) explains that demand-related factors account for about 37 percent of the access gap in SSA, accounting for about 42 percent of the access gap in rural areas and 70 percent in urban centres. The study also found significant differences across sub-regions, with central Africa being the most affected by demand-side constraints (accounting for about 80 percent of the access gap), followed by Southern, Western, and Eastern Africa respectively.

In 2018, annual consumption expenditure for SSA households was estimated to be $1,054 compared to $1,167 in South Asia and $4,972 in the East Asia and Pacific region (World Bank, 2019a). At the regional level, there are significant variations in consumption expenditure across SSA countries, with annual consumption expenditure ranging from $4,847 in Namibia to $284 in Democratic Republic of Congo. With 19 of the most unequal countries[32] in the world found in SSA, there are even larger disparities within countries and the remaining unelectrified populations are expectedly amongst the group with the least ability to pay for the service (World Bank, 2020b).

Despite a general acknowledgement of household income as a determinant of electricity access, there are limited studies and empirical evidence demonstrating this.[33] There are studies which have looked at how national income affects electricity access. For instance, Sarkodie and Adams (2020) found that income inequality has a negative effect on electricity access whereas national income levels and human development have a positive impact on access. However, to the best of our knowledge, there are no studies exploring the impact of household incomes on connection rates.

With respect to prices, there are more studies demonstrating how costs and electricity prices influence uptake and usage (Blimpo and Cosgrove-Davis, 2019). A study by Golumbeanu and Barnes (2013) found that SSA had the highest number of countries with connection charges of more than $100 per customer, with the connection cost to a household ranging from $50 to $250. A more recent review by Blimpo and Cosgrove-Davies (2019) indicates that connection costs range from US$78 in Rwanda to as high as

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[32] These countries are South Africa, Namibia, Botswana, Central Africa Republic, Comoros, Zambia, Lesotho, Swaziland, Guinea Bissau, Rwanda. They have Gini coefficients ranging from 50 to 60 percent.

[33] However, there are several studies assessing the relationship between electrification and income, but these studies have generally focused on the impact of electrification on household income. However, the number of studies on the impact on income on electrification is limited.

US$1,303 in Gabon for a typical household living within a 30-meter radius of the nearest pole.[34] For households outside this radius, costs are even higher as additional poles are generally required, with the cost of poles in SSA ranging from US$92 in Togo to US$656 in Gabon (Blimpo and Cosgrove-Davis, 2016). In Tanzania, the average connection cost in 2011 was about $300 for a house within 30 meters of the line but increased to $870 for houses that needed one additional pole to access the service, and to over $1,200 for houses that needed two additional poles (Chaplin et al., 2017; Golumbeanu and Barnes, 2013).

These costs are generally regressive and for several households, they can be prohibitive as it requires years of savings. It has been recommended that service providers offer payment flexibility for connection costs by amortising these costs over a period instead of the general one-off payment requirements (Lee et al., 2016). Even with such flexibility, government support in the form of affordable loans and direct subsidies may be necessary for some households to be able to afford the service (Palit and Bandyopadhyay, 2016; Bhattacharyya and Palit, 2014). In Mali, an increase in access rates from 9.3 percent in 2001 to 12 percent in 2002 was attributed to the government-funded promotional program that enabled consumers to pay their connection fees over an extended period rather than as a lump sum (World Bank, 2005).

Wiring costs can even be more expensive than connection costs (Chaplin et al. 2017; Miller et al. 2015). Household wiring is typically a standard part of household finishing in modern houses in SSA, but some households may delay this until electricity services becomes available. There are also the unique challenges imposed by some architectural designs when it comes to wiring. For instance, mud and thatch houses which are common in rural SSA do not meet the safety requirements for wiring while shanty shelters in informal settlements in urban areas are often ineligible for a connection due to safety concerns (World Bank, 2012). Ahlborg and Hammar (2014) found that only 10 percent of the surveyed sample in Tanzania could afford to meet the structural requirements for a connection. Ready boards[35] are usually recommended as safer alternatives for wiring such premises. However, in several countries including Uganda and Tanzania, these ready boards were rejected by several households as they were regarded as symbols of poverty.

Even when households have been able to connect to the grid, few are able to afford any meaningful usage (Blimpo and Cosgrove-Davis, 2019).[36] Generally, electricity prices are considered affordable if the cost of consuming the subsistence level of 30 kWh per month is not more than 5 percent of household income (Kojima and Trimble, 2016). The Regulatory Indicators for Sustainable Energy - RISE (2018) found that

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[34] In Kenya, Lee et al. (2016) found a connection cost of $412.

[35] The ready board is a piece of board with a breaker, a bulb, switch, and socket.

[36] Low annual electricity consumption levels may reflect the low economic and corresponding low residential consumption.

the poorest 40 percent of households in half of the access deficit countries (mostly in SSA) spent more than 5 percent of their monthly household income on this subsistence level of electricity. This is because not only are household incomes in SSA low, but electricity prices are amongst the highest in the world - with prices as high as $0.39 per kWh in countries such as Liberia and Guinea Bissau.

Under the Self-Help Electrification Programme (SHEP) in Ghana, the government offered wooden poles to connect households in communities within 20 km of an existing network given a minimum number of interested households.[37] However, there were many voluntary disconnections due to affordability constraints (Victor, 2005). Also, while overall electricity connection rates increased (by more than 500 percent between 1991 and 2000), especially in the northern part of the country, per capita consumption fell by almost 20 kWh per person due to affordability challenges. Many households could not afford the service, and arrears and disconnections were prevalent (World Bank, 2005).

It has been argued that whilst connection and wiring costs may be legitimate barriers for uptake, the cost of usage should not impose such a challenge on households. This is because electricity typically replaces other forms of energy such as lantern and kerosene, torch lights and batteries and candles for lighting at night, dry cells for television and radio, and firewood and charcoal for cooking. These sources of energy typically have a financial cost which are higher than the cost of electricity for the same level of service (Chaplin et al. 2012; Golumbeanu and Barnes, 2013). Studies such as the one by Hosier and Kipondya (1993) found that in Tanzania, electricity (given large subsidies) had the lowest price per kWh in comparison to firewood, charcoal, kerosene, and liquid petroleum gas. Berrie (1990) notes that one kilowatt hour (kWh) of electricity used in 60 watts electric light-bulb produces the same amount of light as about 12 litres of kerosene burned in a kerosene lantern, and at typical prices, makes electric lighting about 100 times cheaper than kerosene lighting (Foley, 1990). Chaplin et al. (2012) notes that not only is electricity cheaper, but within a few years after connecting to grid electricity, the potential savings that accrue to households are usually enough to even cover the fixed costs of connecting to the grid.

However, it is important to note that electricity consumption in newly connected households is typically higher because households acquire more appliances such as televisions and refrigerators or leave their lights on for longer periods of time than they would their lanterns or torch lights[38]. In Tanzania, some households

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[37] Communities within 20 kilometres of a medium-tension electricity line built low-voltage distribution poles themselves, thereby reducing the utility company's cost of extending the grid.

[38] This effect is similar to an economic phenomenon called the rebound effect which refers to observed responsiveness of energy demand to energy prices as consumers consume more due to reduced costs. See Orea et al. (2015). In this

reported large increments in their energy bills particularly those that had started using large appliances (Miller et al., 2015). In Benin, it was found that some households did not understand the billing process and, in some cases, did not even realise that they would have to pay a monthly fee in addition to the lifeline quotas (Peters et al., 2009).

Energy efficiency has been found to make the cost of new electricity connections less burdensome in several countries as it avails energy that would otherwise have been wasted (du Can et al., 2018; van Ruijven et al., 2012; World Bank, 2017). Energy efficiency can also move households to higher tiers of access and increase the availability and affordability of the service (Bhatia and Angelou, 2015; Fowlie and Meeks, 2020). Van Buskirk (2014) found that shaving a single watt from the load of an off-grid appliance resulted in lower initial solar package costs, improved service, or both. The study further indicates that the upfront cost of a typical off-grid energy system can be reduced by as much as 50% with super-efficient appliances and right-sized solar photovoltaics (PV) and batteries, while delivering equivalent or even greater services.

However, articulating energy efficiency in SSA can be complex given the suppressed nature of consumption in the region and ongoing efforts to industrialise SSA economies. As at the end of 2019, 24 of the countries in SSA were Low Income countries (with a GNI per capita of $1,025 or less),[39] 17 were Lower Middle-Income Countries,[40] while 6 were Upper Middle-income countries.[41] As these economies become more industrialised, higher energy consumption would be a natural part of this transition. Thus, industrial-scale electricity that is affordable, safe, and reliable, is an energy policy and economic growth imperative for SSA countries.

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case, as the price per kWh reduces, consumers are incentivized to leave their lights on for longer periods of time as well as acquire larger gadgets which typically leads to an overall increase in consumption.

[39] Benin, Burkina Faso, Burundi, Central African Republic, Chad, Congo Dem. Rep, Eritrea, Ethiopia, Gambia, Guinea, Guinea-Bissau, Liberia, Madagascar, Malawi, Mali, Mozambique, Niger, Rwanda, Sierra Leone, Somalia, South Sudan, Tanzania, Togo, Uganda.

[40] Angola, Cabo Verde, Cameroon, Comoros, Congo Republic, Cote d'ivoire, Eswatini, Ghana, Kenya, Lesotho, Mauritania, Nigeria, São Tomé and Príncipe, Senegal, Sudan, Zambia, Zimbabwe.

[41] Botswana, Equatorial Guinea, Gabon, Mauritius, Namibia, South Africa.

3.3. Methodology

This section presents the methodology for this study. It describes the application of a SFA approach to measure electricity access performance and the econometric specification of the model estimated. It also presents an overview of the data used and their sources. As the theoretical foundations of SFA and frontier methodologies were presented in Section 2.3, the presentation of the methodology for this study focuses on the economic model only to avoid repetition.

3.3.1. A Stochastic Frontier Model to Measure of Electricity Access Performance

In this study, the production frontier is modelled as an equation expressed as $y = f(x, \beta)\exp(v - u)$, where y is the outcome variable, x is a vector of inputs, β represents parameters to be estimated and '$v - u$' represents a convoluted error term. The first part of this error term, v, is a two-sided random disturbance that captures the effects of statistical noise and measurement errors associated with the functional form, while the term u is a one-sided random term that captures technical inefficiency.[42] This can be presented as:

$$\ln(y) = \ln f(x, \beta) + v - u \qquad (7)$$

Based on the conditional mean of the inefficiency term proposed by Jondrow et al. (1982), the efficiency level for each observation can be easily obtained from the estimates of u. The efficiency obtained with this model is a measure bounded between zero and one (or 100%). The difference between 1 and this measure of efficiency shows the rate of electricity access that could be increased in this country at current levels of reforms.

3.3.2. Model Specification

The econometric specification of our basic ALS model with a translog specification is as follows:

$$\ln y_{it}(x, y) = \alpha + \sum_{k=1}^{K} \beta_k \ln x_{kit} + 0.5 \sum_{k=1}^{K} \sum_{l=1}^{K} \beta_{kl} \ln x_{kit} \ln x_{lit} + \gamma z_{it} + v_{it} - u_{it},$$

$$i = 1, \dots, N \qquad (8)$$

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[42] These error terms are assumed to be identically distributed across observations, distributed independently of each other and uncorrelated with the explanatory variables.

where α, β, and γ are parameters to be estimated, z represents control variables, i indicates the ith observation, t stands for the period of observation, and all the variables are defined as before. The error term v is assumed to be normally distributed, and u follows a half-normal distribution.

For this study, I utilise three different specifications of our model. The first two are a Cobb-Douglas and a translog specification, both with a homoscedastic error term. However, the shortcoming of these two specifications is that they do not incorporate certain possible drivers of countries' performance inefficiencies, which can lead to biased estimates of the frontier coefficients and the inefficiency scores (see Caudill and Ford, 1993). Therefore, I also estimate a translog model with a heteroscedastic error term that allows us to incorporate variables as inefficiency determinants through the pre-truncation variance of the inefficiency term assumed to have a half-normal distribution.[43]

3.3.3. Data

We utilise a dataset that comprises an unbalanced panel for 46 SSA countries from the year 2000 to 2017. Data used in this study were obtained from the United Nations and World Bank databases as well as online resources of relevant sector institutions in the countries observed.

We consider the percentage of the population connected to a source of electricity, i.e., connection rates, as the outcome and hence dependent variable in our model. As explanatory variables, I include three reform steps (i.e., vertical unbundling, the presence of a regulator, and private participation in the ownership and management of electricity assets) and three indicators of reform performance, (i.e., installed generation capacity per capita, plant load factor, and technical network losses) as well as energy intensity as an indicator for energy efficiency. The sector-level variables are considered as inputs as they are actions within the electricity sector and can subsequently be effectively influenced with sector policies for desired outcomes. These variables are interacted in the model, but interactions are restricted within group (i.e., reform steps interacted with reform steps and indicators of reform outcomes interacted with indicators of reform outcomes). This is because reform steps are inputs for the included outcomes, and this could cause multicollinearity issues in the model specification.

All other variables, i.e., macroeconomic, and institutional, are included as control variables. These include GDP per capita, population density, the geographical size of countries, household consumption expenditure as a proxy for household income, and natural resource rents. Finally, the Voice and Accountability (VA)

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[43] For a discussion on the alternatives to introduce inefficiency determinants in SFA and an application to the electricity sector, see Llorca et al. (2016).

dimension of the WGI is considered as the measure of institutional quality. The percentage of GDP from natural resource rents, private sector participation in the operations of electricity services, population density, VA, household income, GDP, and vertical unbundling are also included as determinants of inefficiency.

Variable	**Description**	**Descriptive Statistics**
Connection Rates ***(connect)***	The percentage of the population connected to a source of electricity (%)	Max = 100 Min = 1.8 Mean = 35.7 Std. Dev.= 23.8
Reform Steps		
*Vertical Unbundling ***(unb)***	Legal unbundling - separate jurisdictions for generation, transmission and coupled distribution and retail	Max = 1 Min = 0 Mean = 0.18 St. Dev. = 0.38
Sector regulator ***(reg)***	The presence of an autonomous sector regulator	Max = 1 Min = 0 Mean = 0.74 St. Dev. = 0.44
*Private participation ***(pi)***	Private participation in part or all segments of the ESI in the form of management service contracts, leases/affermage contracts, concessions, divestments etc. This includes brownfield public-private partnership arrangements only.	Max =1 Min = 0 Mean = 0.26 St. Dev. = 0.44
Reform Outcomes (Technical Efficiency Indicators)		
Installed Generation capacity per capita ***(gencap)***	Measures the level of generation capacity per capita. It is calculated as (Net Installed Generation Capacity in kW/total population)	Max =1.61 Min = 0.01 Mean = 0.12 Std. Dev.= 0.19
Plant Load Factor ***(plf)***	Measures the efficiency of the generation assets. It is calculated as (Total electricity production/ (Net installed generation capacity*number of hours in the year)	Max = 0.88 Min = 0.05 Mean = 0.41

		Std. Dev.= 0.15
Transmission & Distribution Losses ***(losses)***	Measures the efficiency of transmission and distribution assets. It is calculated as the sum of technical network losses divided by total electricity supply (where supply is the sum of domestic production and net imports).	Max= 0.58 Min= 0.032 Mean= 0.07 Std. Dev.= 0.16
Energy efficiency ***(ee)***	Measures the efficiency with which electricity is used in the production of each unit of GDP. It is calculated as total electricity consumption divided by GDP and it is measured in $US	Max= 1.89 Min= 0 Mean= 0.22 Std. Dev.=0.28
Sectoral or Macroeconomic Variables		
*Gross domestic product per capita ***(gdp)***	Measured as the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is measured in US$.	Max= 22942.6 Min= 111.9 Mean= 1860.6 Std. Dev.= 2978.9
*Household Consumption Expenditure - Private ***(Income)***	Used as a proxy for household income, this indicator is the market value of all goods and services purchased by households. It includes durable products such as cars, washing machines and home computers, fees to governments for permits and license and imputed rents. It does not include purchases of dwellings. Data is in constant 2010 US dollars and in per capita terms.	Max = 5432.3 Min = 180.6 Mean = 1104.1 Std. dev. = 1084.2
*Natural Resource Rent ***(nrr)***	This measures the percentage of national income from natural resources. It is measured in percent.	Max= 84.2 Min= 0.1 Mean= 12.7 Std. Dev.= 12.1
Geographic Size ***(size)***	This measures the land area of a country in square kilometres.	Max= 2267050 Min= 460 Mean= 462238.2 Std. Dev.= 495527

*Population Density ***(pd)***	The refers to the number of persons per square kilometre	Max= 485.6 Min= 2.2 Mean= 80.3 Std. Dev.= 92.2
Institutional Variables		
*Voice and Accountability ***(va)***	This is a dimension of the WGI which captures perceptions of the extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and a free media. It ranges from -2.5 to 2.5.	Max = 1.0 Min = -2.22 Mean = -0.61 Std. dev. = 0.73
Note that the variables with *are introduced in the model as inefficiency determinants and in the frontier.		

Table 3.3-1. Data Definitions and Descriptive Statistics

3.4. Results and Discussion

The interpretation of the results in our estimated models are direct. A positive (negative) coefficient of the explanatory variables indicates a positive (negative) relationship with the dependent variable. Table 2 presents the parameter estimates for the three specifications of our model, i.e., a Cobb-Douglas, a translog without inefficiency determinants, and a translog with *pi, lpd, unb, va, lnrr, lincome,* and *lgdp* as inefficiency determinants. We carried out Likelihood Ratio (LR) tests to compare the three models. The test value when comparing the Cobb-Douglas and the translog without inefficiency determinants is 149.19***, while the values of the test when comparing the translog with inefficiency determinants against the Cobb-Douglas and the translog without inefficiency determinants are 206.38*** and 57.19*** respectively. These values indicate the translog with inefficiency determinants is a superior model to both the Cobb-Douglas and the translog models without inefficiency determinants. Subsequently, these two homoscedastic models are rejected in favour of the translog model with inefficiency determinants. I present the results of the three models but discuss the results of the translog model with inefficiency determinants.

As shown in Table 2, the coefficient of *gencap* is positive and significant at 1% significance level. This shows that the rate of increase of net installed generation capacity per capita is positively correlated with the rate of electrification. This finding is as expected as generation capacity adequacy is a pre-requisite for access expansion to prevent disruptions to existing operations. In fact, in some SSA countries, access expansion is a common rationale for developing large-scale generation projects such as hydropower. For instance, in Cameroon, one of the objectives for the developments of the Natchigal and Memve'ele hydropower plants was to support electrification plans to reach 88 percent of the population by 2022. In Ethiopia where current electrification rates are around 45 percent, the Government has been working to expand the generation base to about 25 GW[44] by 2030 to support electrification plans and the Government's Growth and Transformation Plan to transform Ethiopia from a developing country to a middle-income country by 2035.

	Cobb-Douglas	**Std. error**	**Translog**	**Std. error**	**Translog with Ineff. Det.**	**Std. Error**
Dependent Variable: **lconnect**						
Explanatory Variables						
log gencap	0.26***	0.04	0.30***	0.05	0.45***	0.03
log plf	-0.08**	0.04	-0.05	0.06	-0.02	0.04
log losses	0.09***	0.03	0.00	0.04	-0.03	0.03
log ee	-0.12***	0.04	-0.18***	0.05	-0.37***	0.03
log gdp	0.23***	0.06	0.21***	0.07	0.12***	0.04
log pd	0.05***	0.02	0.08***	0.02	0.08***	0.01
log nrr	-0.05**	0.02	-0.02	0.02	0.02***	0.01
log income	0.14**	0.07	0.25***	0.07	0.01	0.05
unb	0.01	0.05	-0.08	0.14	-0.29***	0.08
reg	0.10***	0.04	0.03	0.05	0.10***	0.03
pi	0.01	0.04	-0.15*	0.09	-0.10**	0.05
size	-0.00***	0.00	-0.00	-0.00	-0.00***	0.00
va	0.06**	0.03	-0.06*	0.03	0.15***	0.02
unbreg			0.09	0.15	0.16*	0.09
unbpi			0.19*	0.10	-0.02	0.06
regpi			0.23**	0.10	0.06	0.06
0.5(log gencap)^{2}			-0.20***	0.03	-0.08***	0.02
0.5 (log *plf*)^{2}			0.33**	0.16	0.08	0.11
0.5 (log *losses*)^{2}			-0.16**	0.06	-0.24***	0.04

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[44] Amongst this is the development of the 6,350 MW Great Ethiopian Renaissance Dam which was about seventy percent complete at the end of 2019.

0.5(log ee)^{2}			-0.24***	0.06	-0.13***	0.03
log gencap log plf*			0.17***	0.05	-0.12***	0.03
*log gencap*log losses*			0.15***	0.04	0.01	0.04
*Log gencap*log lee*			0.12***	0.03	0.10***	0.02
*log plf*log losses*			-0.17*	0.10	0.25***	0.08
*Log plf*log lee*			-0.05	0.08	-0.01	0.04
*Llosses*log lee*			0.02	0.05	-0.07*	0.04
lambda	4.56***	0.05	3.21***	0.05		
-cons	0.71***	0.09	0.75***	0.09	0.18***	0.05
Inefficiency determinants						
pi					0.60***	0.23
va					1.24***	0.20
lnrr					0.80***	0.14
lpd					0.67***	0.09
lincome					-1.34***	0.38
lgdp					-0.85**	0.33
unb					-0.83***	0.32
Inefficiency term (u)	-0.74***	0.10	-1.18***	0.12	-6.03***	0.70
Noise Term (v)	-3.78***	0.33	-3.51***	0.25	-4.42***	0.19
e (sigma_u)	0.69***	0.03	0.55***	0.03	0.65***	0.04
e (sigma_v)	0.15***	0.02	0.17***	0.02	0.11***	0.01

Table 3-2. Parameter Estimates

Significance code : * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

On the other hand, we found the coefficient of *plf* and *losses* to be insignificant, indicating that the rate of increase in the load factor of the generation portfolio has no significant correlation with electrification rates. This finding can be explained by the fact that while an increase in load factor and a reduction in network losses increase electricity supply, it is a variable supply source. This makes electricity supply boosts from these efficiency improvements unreliable, and policymakers are generally reluctant to base electrification decisions (which are permanent) on impermanent supply sources.

We found the coefficient of *ee* to be negative and significant, indicating a negative relationship between energy intensity and the rate of electrification. This finding is as expected as demand-side efficiency have been found to minimise the financial, social, and environmental costs of energy supply (de la Rue du Can et al., 2018; World Bank, 2019b). It has also been described as the lowest-cost option in the range of fuel possibilities and recommended as the ‘first fuel’ resource to be utilized in energy policy and sustainable growth efforts (World Bank, 2017b).

With respect to the reform steps, I found the coefficients of *unb* to be negative and significant when included as an explanatory variable. This indicates that vertical unbundling of the electricity sector is negatively correlated with the rate of access expansion. This finding can be explained by the changes in commercial incentives following the unbundling of SSA electricity sectors as unbundling is generally complemented with the commercialisation of the sector utilities. Distribution utilities are often converted to limited liability companies following unbundling and are naturally inclined to make investment decisions on the basis of profitability. Thus, in the absence of an effective public program for electrification, access expansion is curtailed as the investment costs of expanding electricity services to several unelectrified areas in SSA can be very high compared to expected returns. I also included *unb* as a determinant of the inefficiency term in the model. I found the coefficient of unbundling to be positive indicating a positive correlation between unbundling and the inefficiency term. This finding shows that vertical unbundling is not only negatively correlated with the rate of access expansion but also a source of inefficiency in the model.

I found the coefficient of *pi* to be negative and significant when included as an explanatory variable in the preferred model. This indicates that private sector participation in the ownership and management of power utilities is negatively correlated with the rate of access expansion. This finding can be explained by the profit incentives of private companies which dissuade investments in new connections given that prospective consumers often have a limited ability to pay. The incompatibility of the commercial goals of power utilities with access is observed in the deterioration of utility financial performance in recent years as SDG-7 efforts accelerate the pace of electrification in SSA (Balabanyan et al., 2021).

For instance, in Liberia, access expansion was a key performance indicator in the MSC with Electricity Supply Board Ireland – ESBI (Mathematica, 2020). However, the Contractor has struggled to achieve much under this KPI in large part because of the precarious financial position of the utility which compels it to prioritise keeping the lights on for existing consumers and keeping the company afloat. I also included *pi* as a determinant of inefficiency and found a positive and significant relationship between the inefficiency term and *pi*. This finding also shows that private participation in ownership and management was a source of inefficiency in the model. Thus, I allege a similar effect of vertical unbundling and private sector participation on electrification outcomes.

I found the coefficient of *reg* to be positive and significant. This indicates that the presence of a sector regulator is positively correlated with the rate of access expansion. This finding is not surprising given the important role the sector regulator plays in ensuring that vulnerable groups are not excluded or discriminated against in the provision of electricity services.

With respect to the control variables, I found the coefficient of *gdp* to be positive and significant when included as an explanatory variable. This finding shows that the rate of increase of a country's wealth as represented by its GDP per capita is positively correlated with the rate of electricity connections. Thus, the pace of economic growth may correspond to the pace of electrification in SSA countries. I also included *gdp* as a determinant of the inefficiency term. I found a negative relationship between *gdp* and the inefficiency term indicating that the rate of increase in national wealth correlates with a reduction in inefficiencies in the model.

I found the coefficient of *nrr* to be positive and significant when included as an explanatory variable. This finding indicates that the percentage of GDP from natural resource rent is positively correlated with the rate of electrification in SSA. This finding suggests that SSA governments may be investing in electricity infrastructures as a means of distributing resource rents as initially thought. I also included *nrr* as a determinant of inefficiency. I found the coefficient of *nrr* to be positive indicating a positive correlation between *nrr* and the inefficiency term. This shows that as natural resource rents increase, inefficiencies in the rate of access expansion also increases. This suggests that electricity access may be one of the channels that resource curses perpetuate inequality in SSA countries.

At the micro level, I found the coefficient of *income* to be insignificant when included as an explanatory variable. This finding shows that the rate of increase of households' ability to pay for goods and services has no direct relationship to the rate of access expansion in SSA. I also included income as an inefficiency determinant. I found that income was a source of inefficiency in the model with a significant and negative relationship between the coefficient of household income and the inefficiency term. This finding indicates that the ability of households to pay for goods and services reduces inefficiencies in electrification policies in deregulated electricity systems.

I found the coefficient *pd* to be positive and significant when included as an explanatory variable in the model. This can be explained by the implications of population density for costs per connection. It is cheaper to provide electricity services in densely populated areas as the cost per capita for the service is negatively correlated with the number of users. Also, people are more likely to move to areas where electricity infrastructures already exist, and thus existing electricity infrastructures would be utilised by more people overtime. Included as a determinant of inefficiency, I found the coefficient of *pd* to be positive and significant, indicating a positive correlation between population density and the inefficiency term. This finding is interesting as it brings attention to the issue of slum electrification in SSA. An estimated 238 million people in SSA live in slums (UN 2019; World Bank 2018). Residents in such areas are often poor, living in shanty informal shelters which do not often meet the standards for a legal electricity connection. As a result, illegal connections are very common in these areas undermining electrification efforts in several SSA countries.

The coefficient of the *size* variable was found to be negative and significant but negligible. This indicates that the geographical size of a country is negatively corelated with its electricity access performance. This finding shows that smaller countries are expected to have higher electricity access rates. This finding is as expected as one could argue that it would be easier (cheaper) to electrify smaller countries than it would be larger ones.

With respect to the institutional variables, I found the coefficient of *va* to be positive and significant. This indicates that the extent to which the citizens of SSA countries can participate in selecting their governments, freedom of expression and association as well as the freedom of the media is positively correlated with the rate of electrification. This finding is not surprising, as one would expect that in countries where citizens are able to express and assert their wants and needs and governments can be held accountable for their mandates, there would be a stronger incentive to provide social infrastructures like electricity. However, I also included *va* as a determinant of inefficiency and found a positive relationship between va and the inefficiency term. This finding shows that the voice of people and the accountability of governments was a source of efficiency in the model. This finding is unsurprising as in most SSA countries, voice is concentrated amongst urban populations and the political elite, with the power to effectively mobilise against governments. Thus, unelectrified populations who are typically lesser influential groups may be less effective in influencing public policy on access. Rather, elite groups may even be successful in diverting resources into avenues that are favourable to them. For instance, a government would be interested in investments to curtail outages than invest in new connections. In Ghana for instance, an extensive load-shedding – dubbed "*dumsor*" made the incumbent government highly unpopular. The political strategy of the government to assuage the electorates was restoring the stability of supply rather than providing access in new areas. Despite the extensive efforts, however, the incumbent Government lost the election in 2016.

3.5. Conclusion and Policy Implications

In this study, I investigate the determinants of electricity access performance in SSA and its relation to sector reforms using a dataset of 46 SSA countries from 2000 to 2017. I define a production frontier for electricity access performance with connection rates as the dependent variable, and I model this as a function of a set of reform steps including vertical unbundling, private sector participation in the management and ownership of utilities, and the presence of a sector regulator. I also included three indicators of reform performance i.e., installed generation capacity, plant load factor and technical network losses as well as energy intensity as an indicator for energy efficiency.

In order to understand the effects of the macroeconomy on electrification outcomes, I included GDP per capita and natural resource rents (as indicators of national wealth) household consumption expenditures (as an indicator for household income levels) as control variables. I also included population density and the geographical size of countries as control variables in addition to perceptions about Voice and Accountability which is a dimension of the World Bank Governance Effectiveness index as a measure of institutional quality. Finally, I included natural resource rents, population density, household income, GDP, unbundling, voice and accountability, and private sector participation in the management and ownership of electricity assets as determinants of inefficiency.

The results indicate that the presence of an electricity sector regulator is positively correlated with the rate of electrification and negatively correlated with inefficiencies in the model. I also found vertical unbundling and private sector participation in ownership and management to be negatively correlated with electrification outcomes and sources of inefficiencies in the model.

I found a positive relationship between the rate of increase of installed generation capacity per capita and electrification rates. On the other hand, the rate of increase in plant load factor and reduction in network losses had no relationship with electrification outcomes. Energy intensity was also found to be negatively correlated with the rate of electrification indicating the positive relationship between energy efficiency and access performance.

The results also show that the wealth of a country and its households are positively correlated with the rate of electrification and negatively correlated with inefficiencies in the model. The percentage of income from natural resource rents was found to be positively correlated with access performance. However, natural resource rents were a source of inefficiency in the model. Population density was found to be positively correlated with the rate of electrification but was a source of inefficiency in the model.

With respect to the effects of institutional quality, the results show a positive relationship between voice and accountability and the rate of access expansion. However, a skewed concentration of voice and its implicit accountability bias was found to be detrimental to electrification outcomes.

I conclude that the adequacy of generation capacity and the efficiency with which electricity is used has a direct and positive relationship with the ability to provide the service to those unserved. While the wealth of a country may be a significant determinant of electrification outcomes through the supply side, household incomes are also as important on the demand side. Reform steps including unbundling and private sector participation in management and ownership are incompatible with increasing electricity access. However, private sector participation reduces the inefficiencies of electrification programs in liberalised electricity systems. Contrary, the presence of a sector regulator is important for improved electrification outcomes.

Policymakers should ensure that there is adequate reserve margin in generation in the pursuant of electrification goals and promote energy efficiency as part of a holistic electrification strategy. Reform steps such as unbundling and private sector participation in ownership and management of utilities should have explicit provisions for access expansion including financing for electrification programs. Urban planning should promote the clustering of populations to facilitate easier provision of electricity services given the positive relationship between population density and electrification rates. Electrification strategies should be inclusive and intentional about providing electricity services in slum areas. Electrification programs should be bundled with productive use activities that increase household income to break demand-side barriers and facilitate uptake.

4. Cost Efficiency in Liberalised Electricity Sectors Without Competitive Markets: *The Case Of Small Electricity Systems.*

4.1. Introduction

As articulated with the Structure–Conduct–Performance (SCP) paradigm of neoclassical economic theory of Industrial Organisation, the structure of a market is a fundamental determinant of the conduct of firms within it and their eventual performance (Mason, 1937; Bain, 2014). Thus, by influencing industry structures, one can affect performance through a direct relationship that spans from structure through conduct to performance (Church and Ware, 2000; Lelissa and Kuhil, 2018).[45] Structure refers to the level of seller and buyer concentration, the height of entry barriers and the degree of product differentiation within a given market (Shepherd,1970).[46] Conduct refers to the behavioural patterns of firms as they adapt to the market in which they sell or buy (Bain, 1968). It comprises the various decision-making techniques used in the determination of prices and output levels to achieve economic goals (Lelissa and Kuhil, 2018). Market performance is the economic results that flow from the structure and conduct of firms (Bain, 1968). According to Narver and Savitt (1971), performance is the net result of conduct as measured by net profits, rate of return on equity, efficiency with which capital is used, amongst others. Productive and allocative efficiency (Neuberger, 1997) and growth (Lipcznski et al., 2013) are regarded as important performance indicators. It is often measured by comparing the results of firms in terms of price, quantity, product quality, resource allocation, production efficiency amongst others (Neuberger, 1997). At the core, market performance is reflected in price levels, profit margins, investment levels (Hay and Morris, 1991).

SCP posits that conditions of supply and demand in an industry determines the structure and the degree of concentration in the market which in turn affects the extent of competition among firms in the industry. Specifically, a more concentrated market structure would produce more effective collusion, resulting in sub-optimal profits (Sathye, 2005). Thus, to increase the cost of collusion, market power must be eradicated (Bain, 1951).

Specific to the electricity sector, it was asserted that the observed inefficiencies prior to reforms were the consequence of prevailing monopoly market structures. Subsequently, by eradicating these monopoly market powers in favour of competitive structures, firms will be incentivised to control costs (and prices) and improve the quality of their services (Jamasb et al., 2006; Joskow,1998a; Jamasb, 2002; Demestz, 1973; Nepal and Jamasb, 2015). Thus, the establishment of competitive electricity markets was a critical

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[45] Critics have pointed to various feedback effects in the SCP paradigm i.e., from performance to conduct; from conduct to structure and from performance to structure (see Phillips, 1976).

[46] Other elements of market structure exist, but they are often ignored because they are difficult to observe or cannot be measured (Belleflamme, et al., 2010).

component of the reforms, especially in the pursuant of cost efficiency, improved service quality, and reduced prices (Nepal et al., 2022).

However, over the three decades since the initiation of reforms in SSA, no country in the region has successfully established a competitive wholesale or retail market. Electricity sectors remain partially deregulated, with public vertically integrated structures coexisting with elements of market-orientation (Gratwick and Eberhard, 2008; Foster and Rana, 2020; Sioshansi and Pfaffenberger, 2006; Kessides, 2012; Williams and Ghanadan, 2006; Jamasb et al., 2017; Sen et al., 2018). Reforms remain investment-focused, especially as one in two sub-Sahara Africans do not have access to electricity, generation capacity remains inadequate, and transmission and distribution networks are dilapidated.

In recent years, nonetheless, the effects of the absence of functioning markets in liberalised electricity systems in SSA have become evident, with surging cost of electricity supply and high prices which are unable to cover the full cost of service. Utilities are thus faced with persistent under-recovery of costs that threatens their financial viability (Huenteler, 2017; Briceño-Garmendia and Shkaratan, 2011; Kojima and Trimble, 2016). A study of 39 countries in SSA found that only Seychelles and Uganda fully recovered their operational and capital costs, and only 19 of the 39 countries collected sufficient revenue to cover their operational costs (Kojima and Trimble, 2016). Subsequently, cost-recovery and the financial viability of utilities have become front and centre in energy policy in SSA.

However, discussions on prevailing revenue-cost margins focus heavily on the revenue aspects and inadequately on the cost side. Utility and tariff reforms are the new forms of reforms, with regulatory pressures to increase prices to cover costs and calls for privatization to improve the operational performance of utilities. The role of sector reforms and prevailing markets are often dismissed, with the main argument being that hybrid market structures and their corresponding inefficiencies are the result of incomplete reforms. Thus, electricity systems seeking to address these structural inefficiencies should focus on completing the deregulation process to establish markets.

This perfunctory referrals to incomplete reforms have been obliquely used to justify the superficial and little effort put in examining the structural problems of liberalized electricity systems without markets. However, for many SSA countries, completing the reforms may not be a viable option due to inherent structural issues with an exemplary illustration being small electricity systems which cannot support multiple competitors at an efficient scale. For these electricity systems, emerging hybrid electricity sector structures have proven to be steady state structures and not transitory, indicating the unviability of traditional reform models in delivering cost efficiency in these contexts.

Despite a general acknowledgement of small electricity systems in the reform literature, there is a lack of explicit guidance on alternate pathways to cost efficiency for electricity systems that cannot support competition. In this study, I conduct a synthesis of market-based reforms in the context of small electricity systems. I present the key challenges that emerge in liberalised electricity systems without markets and how they impact electricity costs and prices. I assess the regulatory approaches and privatisation models that have been adopted in place of competition to facilitate contestability and improve the operational performance of utilities drawing on various case studies across the region (Baumol et al., 1982). The purpose of this study is to provide guidance to managing liberalised electricity systems without competitive markets. However, the focus on small electricity systems is to provide a stable analytical framework insulated from dismissive references to non-economic factors that inhibit the completion of reforms. Thus, this analysis is not intended to diminish the reform experiences of larger electricity systems that struggle to establish markets, but in fact has several relevant and useful implications and instructions for these systems as well.

The remainder of this study is organised as follows. Chapter 2 contextualizes small electricity systems from the point of view of reforms. Chapter 3 presents the key challenges in the generation segments of liberalised small electricity systems and the regulatory approaches used to minimise generation costs. In Chapter 4, I examine the main operational challenges observed in the distribution segments of small electricity systems and the approaches that have been adopted to improve quality of service and reduce costs and prices. Chapter 5 concludes the study with recommendations for policy.

4.2. Reforming Small Electricity Systems

A major challenge in the economic analysis of smallness is finding an objective definition for the concept (Fisher, 1967). Staley and Morse (1966) suggest that one can escape the complications of crisp definitions by using a ‘functional’ definition, i.e., a definition based on the context in which it is used (Staley and Morse, 1966). A useful definition of smallness is by Gal (2003) which when adapted to the electricity sector typifies a small electricity system as one that cannot support the optimal number of competitors when catering to demand. In such electricity systems, there is no real risk to losing market share due to economies of scale and scope or barriers such as high transaction costs.

Generally, the literature on small economies attempt to conceptualize smallness in terms of measurable demand-side variables such as population (Brigulio, 2020), economic activity, and geographic size (Gal, 2003; Brigulio, 2020) whether combined or individually. In the case of electricity systems, other key determinants of demand or market size include population distribution, electricity access rates and the degree of regional integration or isolation. For instance, a jurisdiction may be large with a corresponding high demand, but with populations widely dispersed, sub-jurisdictional markets may emerge creating small systems. An example of this is mini grid systems that are emerging as a popular electrification solution in rural SSA (Kirubi et al., 2009). Similarly, a small system within a power pool could be regarded as part of the larger market the pool has created, negating the scale limitations of its sole demand. In addition to these demand factors, in regions with high poverty levels, there can be high latent and suppressed demand due to low access rates, unaffordable electricity prices and service interruptions which create discrepancies between actual and effective demand.

While smallness is best explained from the point of view of demand, its economic implications are best articulated from a supply position. In production economics, there is a Minimum Efficient Scale (MES) at which firms produce at the lowest long-run marginal cost and beyond which there is diseconomies of scale. In the electricity sector, this corresponds to the maximum size of a power plant (which is identical to the firm) to produce electricity at the least-cost.[47] This is largely determined by the technological characteristics of the plant, i.e., hydro, solar, CCGT, nuclear etc as well as other factors such as the age of the plant, amongst others. For instance, the MES of a hydropower plant will be significantly different from that of a CCGT plant or grid-connected solar plant.

Given a level of demand, the MES determines the number of efficient firms that can be accommodated in an electricity market, with the number of efficient firms related to the size of demand, approaching infinity (perfect competition) as demand increases, and approaching zero (monopoly) as demand falls. For the electricity sector, however, it is estimated that effective competition requires at least five generating plants of dispatchable technologies.[48] Against this backdrop, researchers have attempted to define a numeric threshold for categorising electricity system size into small or large. For instance, 1000MW of peak demand has been indicated to be the minimum size for an electricity system to be considered large (Besant-Jones, 2006; Vagliasindi and Besant-Jones, 2013). Foster and Rana (2020) indicate that an electricity sector of at least 3GW of peak demand or 20 TWh of annual energy demand may be considered as large. Based on this rule of thumb, we identify 30 of the 48 SSA countries (electricity systems) as being small when using the

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[47] In a competitive wholesale market, the MES is at the plant level, i.e., the plant and the firm are the same.

[48] A dispatchable source of electricity refers to an electrical power system, such as a power plant, that can be turned on or off, i.e., can adjust the output supplied to the electrical grid on demand. Most conventional power sources such as coal or nuclear power plants are dispatchable. In contrast, many renewable energy sources are intermittent and non-dispatchable. These include sources such as wind and solar power (without battery storage) which can only generate electricity while their primary energy flow is available.

metric of installed generation capacity below 1000MW. When using the metric of 3TWh annual peak demand, 31 countries are identified as small (Table 4.2.1).[49] It is, however, important to note that smallness is a short run concept subject to changes in demand characteristics and technological progress over time. Thus, in the long-run, many small electricity systems evolve and become large.

According to Bain (1968), market concentration, firm size and entry conditions are the basic elements of market structure. Thus, the relevance of system size is most apparent during sector restructuring, and more specifically during unbundling. An integrated electricity sector can be unbundled vertically and horizontally. Vertical unbundling involves the separation of the potentially competitive segments of the ESI generation and retailing) from the natural monopoly networks segments (transmission and distribution). Unbundling can take three forms, i.e., functional/accounting unbundling, legal unbundling, and ownership unbundling, with each form differing from the others by the degree of separation.

Table 4-1. Description of Sub-Sahara Africa electricity Systems in numbers (2019)

Country	Population (million)	Generation Capacity in (MW)	Electrification rate (%)	Peak Demand (GWh)
Guinea-Bissau	1.92	28	31.0	82
Sao Tome and Principe	0.22	29	75.0	86
Comoros	0.85	35	84.3	95
Central African Republic	4.75	44	14.3	149
Lesotho	2.13	75	44.5	933
Chad	15.95	86	8.4	297
Burundi	11.53	87	11.4	336
South Sudan	11.06	131	6.7	576
Gambia The	2.35	137	62.1	312
Sierra Leone	7.81	143	22.7	250
Seychelles	0.98	157	100.0	516
Eswatini (Former Swaziland)	1.15	193	76.9	1,531
Liberia	4.94	195	23.1	433
Cabo Verde	0.55	221	91.4	497

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[49] SSA countries with gross energy demand below 3TWh as at the end of 2020 are included. The list is presented in descending order of demand.

Eritrea	6.1	226	50.9	461
Rwanda	12.63	228	40.4	889
Togo	8.08	230	52.4	1,538
Niger	23.31	324	19.0	1,562
Burkina Faso	20.321	390	18.4	1,799
Benin	11.801	508	40.3	1,620
Madagascar	26.97	546	31.0	2,134
Equatorial Guinea	1.35	554	66.6	750
Namibia	2.45	600	55.2	4,350
Malawi	18.63	603	11.2	2,167
Congo Republic	5.38	606	48.4	3,223
Mauritania	4.53	608	45.8	1,479
Guinea	12.77	621	42.2	1,979
Botswana	2.30	761	70.0	3,951
Gabon	2.17	784	90.7	2,694
Mauritius	1.27	844	100.0	3,192
Somalia	15.44		49.2	367
Mali	19.66	1,015	47.8	2,929
Uganda	44.27	1,256	41.3	4,157
Senegal	16.30	1,432	70.4	4,724
Tanzania	58.01	1,530	37.7	7,918
Cameroon	25.88	1,669	63.5	8,248
Republic of Cote d'Ivoire	25.72	2,233	68.5	9,137
Zimbabwe	14,65	2,346	46.8	8,729
Mozambique	30,37	2,814	29.7	16,240
Zambia	17.86	2,981	43.0	14,152
Kenya	52,57	3,155	69.7	11,731
Congo, Democratic Republic	86.79	3,190	19.1	10,199
Sudan	42.81	4,138	54.0	
Ethiopia	112.08	4,300	48.1	14,075
Ghana	30,42	5,382	83.5	16,885
Angola	31.83	6,156	45.6	15,074
Nigeria	200.96	11,681	55.4	30,521

South Africa	58.56	58,683	85.0	225,913

Source: United Nations and World Bank Databases

In accounting unbundling, the electricity sector remains vertically integrated but there is a reorganisation of accounts to ringfence the costs of each segment of the ESI, i.e., generation, transmission, distribution, and retail. Beyond these changes in book-keeping, there is no material change in sector organisation such as in ownership, management, or staffing. Legal unbundling typically follows functional/accounting unbundling and involves the separation of each segment of the ESI into separate legal entities with its own management and staff as well as accounts. Legally unbundled power utilities (companies) may have a similar ownership structure as it had prior, such as continuous public ownership but may remain connected via a holding company (Foster and Rana, 2020). Finally, and the strictest form, is ownership unbundling, for which accounting and legal unbundling are pre-requisites. This involves a separation of ownership from management, often through the conversion of legally unbundled utilities into limited liability companies or corporations with distinct shareholders and a Board of Directors.

The main rationale for unbundling during reforms pertains to its implications for competition. Specifically, vertical unbundling is argued to facilitate non-discriminatory third-party access to electricity networks, an essential condition for private sector participation and competition. The logic is that a firm controlling the network and, at the same time, involved in the competitive segments of the ESI has the incentive to limit or deny access of other firms to the network through discriminatory access tactics such as pricing or "strategic" investments in grid augmentation. Thus, vertical unbundling presents a structural remedy as it differentiates interests in the competitive segments from those in the networks, subsequently removing the possibility and interest to discriminate. In addition, vertical unbundling has been indicated to enhance transparency and facilitate accountability as it allows easy identification of costs and (in)efficiencies. However, vertical unbundling on its own may not result in improved performance unless matched with proactive steps to address identified issues.

Once the sector has been fully unbundled vertically, it can be unbundled horizontally to create an adequate number of competing firms. This involves the breakdown of existing firms into smaller units to remove the dominance of any one firm. It is often at this point that reforms are curtailed in small electricity systems, as total demand can often be met with one or few firms and de-concentration creates suboptimal firm sizes. In several SSA electricity systems, these limitations are particularly pronounced as pre-reform generation portfolios are dominated by hydropower which are often non-dispatchable and fully amortized. This gives the incumbent generators a competitive advantage of generation at lower cost and in most cases the privilege of priority dispatch. Under such conditions, horizontal unbundling would lead to sub-optimal outcomes giving existing generators natural monopoly powers.

In the absence of horizontal unbundling and subsequently competition, however, arguments for vertical unbundling also weakens. This is because the separation of sector activities leads to loss of vertical economies, removes complementarities in technical coordination, and creates information asymmetry given the separation of sector management, ownership and regulation and the concomitant separation of interests and incentives (Kaserman and Mayo, 1991; Nemoto and Goto, 2004; Arocena and Oliveros, 2012; Gugler et al., 2017; Armstrong and Read, 2004; Nepal et al., 2018). In countries where payment discipline is lacking, sector financial challenges may also be amplified as debts are cascaded across the various unbundled segments of the ESI (Foster and Rana, 2020). Thus, given that third party access can be regulated or negotiated effectively, and transparency is not a sufficient condition for improved performance, the economic justification for vertical unbundling in small electricity systems tends to weaken especially when one considers the high transaction and economic costs involved. However, decisions to vertically unbundle are best made at the country-level based on a robust economic analysis that rightfully reflects the economic costs and benefits in each context.

Whether or not vertical unbundling is chosen, the predominant market structure that prevails in small electricity systems is the single buyer model. The single buyer model was first known to appear in developing countries in the 1990s following the initiation of reforms as Governments strived to relieve capacity shortages while conserving scarce public resources (Asantewaa et al., 2022). The liberalization of the sector allowed IPPs to generate electricity, which was then sold to sector utilities, often state-owned distribution companies in vertically unbundled electricity systems or the vertically integrated public corporation. These IPPs typically enter long-term Power Purchasing Agreement (PPAs) with an off-taker, which are typically utilities or the Government, to which they sell the power they generate.[50]

In the subsequent sections, I present the regulatory approaches used to incentivize cost efficiency in small electricity systems and the effectiveness of these mechanisms drawing on various case studies from the region. As the largest cost components of electricity service delivery are generation and distribution costs (together accounting for about 90% of total electricity supply costs), these two segments are often the focus of reforms and cost-reduction efforts and subsequently the focus of our discussion.

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[50] IPPs are not utilities but limited liability companies often privately-owned or publicly owned special purpose vehicles.

4.3. Generation Cost Efficiency in Liberalised Small Electricity Systems

In fully deregulated electricity systems, licensed generators produce electricity which they sell in a wholesale market to an offtake entity (often a distribution company) for onward resale to end-users through retail markets. It was posited that the establishment of competitive wholesale markets would incentivize cost control by shifting the risks of technology choices, construction costs and operational mismanagement from consumers to producers (Joskow, 1997, 1998a, 1998b; 2005, 2006, 2008; Jamasb et al., 2005, 2006; Philipps, 1971; Besant-Jones, 2006). Then retail competition will subsequently facilitate the transfer of these efficiency gains to consumers in the form of lower costs and or improved quality of service (Guasch, 2004; Demsetz, 1988; Bain, 1951, 2014; Armstrong et al., 1994). In such markets, prices are determined through auctions, where generators bid to supply the market demand. A generator offers a price at which they can supply a specific quantity of electricity, and if the bid is successful, it is said to “clear” the market. The cheapest generation resource will “clear” the market first, followed by the next cheapest option, and so forth until demand is met.[51] When supply fully matches demand, the market is “cleared,” and the price of the last successful bid resource (plus other market operation charges) becomes the wholesale price of power.

In small electricity systems where such markets do not exist, new generation capacity is often procured through contracts following a regulated planning process called Integrated Resource Planning (IRP). In this, utilities propose, and regulators consider long-term power generation needs based on the economics of different approaches, as well as operational and reliability trade-offs associated with different resource mixes. Based on these plans, new generation capacity is procured, ideally through a competitive process to force all potential generators to bid against one another publicly and transparently to reduce energy prices (Eberhard and Shkaratan, 2012). Once the winning bid is selected through this procurement process, a PPA is signed between the generator (IPP) and the offtake entity.

PPAs have a two-part pricing, a capacity charge, and a volume charge. Capacity charges ensure that investors recover the full capital costs of their investments and an allowable RoR on the invested capital. It can be conceptualised as the amortised capex of a generation plant, i.e., the cost of constructing the power plant (including financial costs), a return on the investment, and the costs of maintaining the power plant to ensure its availability when needed. On the other hand, volume charges cover the operating costs of running a power plant and subsequently incurred only when the plant runs. Thus, in theory, while a capacity charge is incurred by virtue of capex sunk, volume charges are directly related to kilowatt hours produced.

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[51] This process is called economic dispatching, which ensures the successive dispatch of the generation source with the lowest "marginal" or operational costs to the point where all load is met or the generation source hits its capacity constraint, whichever comes first.

As PPAs are legally binding contracts, the opportunities for cost reduction are prior to contracting and often achieved through some policy and regulatory provisions.

Regulators are not party to the commercial relationship between generators and offtake utilities. However, they can influence these contracts through the pre-specification of cost criteria that would be considered in the rate setting. This may include guidelines about planning, procurement, and in some cases contract terms, which an off-taker must consider in its power purchases if it expects to fully recover its costs through tariffs.

In SSA, enforcing regulatory standards have proven to be challenging. System planning is weak, with new generation capacity often procured under extreme pressure. Many electricity systems do not have an up-to-date least-cost plans, and the few that do, they are not linked to procurement. Modelling inaccuracies are also common in these plans, especially pertaining to demand projections which often deviate significantly from actual demand in magnitude and in timing (Eberhard et al., 2016). This is largely because system planning is a technical exercise that require high technical capacity, something that is lacking in many small electricity systems, especially in countries affected by fragility, conflict, and violence (Nepal and Jamasb, 2012). Thus, it is not uncommon to have shortages kick in before new capacity is constructed. This has led to an increased popularity of mobile power plants (often called Emergency Power Plants - EPPs) in the region. In West Africa alone, all countries (except for Liberia, Togo, and Niger) have had some experience with EPPs in the last ten years, with EPPs accounting for an estimated 1527 MW of generation capacity (17% of total net installed generation capacity) as at the end of 2019.

In addition, most new generation capacity in the region continues to be sourced directly despite extensive evidence that competitive procurement of new generation capacity tends to reduce the levelized cost of electricity generated by IPPs (Eberhard et al., 2017). This practice stems from initial engagements with IPPs during the earlier stages of reforms when SSA countries were indebted, and public utilities were insolvent (Eberhard et al., 2017). Earlier IPPs benefited from generous PPA terms in the forms of high prices, and investment risk mitigation mechanisms such as guarantees and escrow accounts to mitigate credible risks to investments in the region at the time (Gratwick and Eberhard, 2011). Despite considerable improvement in the financial position of SSA utilities and Governments over the years, these risk perceptions continue to persist, with the Rate of Return (RoR) on IPP investments often significantly above actual risks. The World Bank estimates that the costs of power procured through IPPs in the region may represent a 40% mark-up over corresponding economic costs (Foster and Rana, 2020).

IPP transactions are often associated with strong and entrenched vested interests due to their high-value nature. These are often shrouded in formal and informal local content requirements which legitimizes the allocation of project shares to political elites with the ability to influence regulators and compel regulated firms to consider their interests (Albalate et al., 2015). These special interests often dominate procurement processes, even when these are done competitively. This may be in the forms of unclear and restrictive tendering procedures, discriminatory release of information, strategic selection of award criteria and predatory clauses (Auriol et al., 2016; Iossa and Martimort, 2015). Thus, competitive procurement must be done in an open and transparent manner to attract high quality bids.

Contracting terms can also be anti-competitive. For instance, "take-or-pay" clauses or volume risk shifting conditions in PPA contracts mandates a minimum purchase commitment of generated power.[52] This is often useful for developers in accessing debt financing on limited recourse terms but implies a lock-in of a certain market share over the duration of the PPA (often between 10 to 30 years). This implies that small electricity systems cannot take advantage of newer and cheaper generation technologies even if the cost savings from a switch is higher than the capital cost of existing vintage plants. The opportunity cost for switching will now include the "take-or-pay" costs, and these are often prohibitive. This makes it challenging for small systems to fully participate in regional electricity markets, especially if IPPs had not been procured under the value-for-money conditions discussed earlier.

The World Bank estimated that about sixteen SSA countries (mostly small systems) would benefit from reduced electricity prices by importing more than 50% of their power (Foster and Rana, 2020). This is largely because, while many small and fragile states are struggling with severe energy constraints, their neighbours are endowed with abundant gas, hydropower and solar resources that often exceed their domestic demand needs. For example, Mano River countries have surplus hydropower in the wet season but suffer power shortages in the dry season, while Sahelian countries have the potential to generate excess solar energy during the day but would face shortfalls in the night. Countries stand to make savings ranging from $0.01 to $0.07 per kilowatt-hour (kWh), with the largest beneficiaries being smaller electricity systems (Foster and Rana, 2020). Regional electricity trade could also facilitate emission reduction by creating larger balancing areas to facilitate the integration of variable renewable energy resources while displacing domestic thermal generation with renewable energy (Chattopadhyay and Fernando, 2011, Singh et al., 2018). Without a concerted effort to address the contractual rigidities of national contracts, the participation of small systems in regional markets will be limited and small electricity systems would be slow to respond to technological progress and decarbonise their electricity sectors.

In principle, regulators should be able to enforce these value-for-money criteria to ensure that small systems achieve cost-efficiency in generation. In practice, however, this can be challenging to enforce given the

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[52] In some electricity systems, "take-or-pay" quantities imply no need for capacity charges as the capex associated with the production of the agreed take-or-pay" quantities are often covered in the agreed payments.

pervasive relevance of the electricity sector in all other aspects of the economy and the high economic and socio-political costs of its poor performance. The sector is thus of high national and political interest and an implicit liability in most countries.[53] Subsequently, the burden of regulatory insubordination often falls on consumers, directly or indirectly, especially if utilities are state-owned.

If the regulator disqualifies ineligible costs from tariffs, utilities seek external sources of financing such as short-term debt to cover this margin or accumulate payment arears to sub-contractors, i.e., generators, fuel suppliers, lenders, and other utilities. As both strategies are not sustainable, arrears and or debt often accumulate to financially unsustainable levels, and Governments are forced to intervene with various fiscal transfers and subsidies at the expense of other public services such as potable water, education, health, and social protection. These subsidies also interfere with consumption signalling, leading to higher consumption, pollution, and other externalities (Badiani et al., 2012; Monari, 2002; Rentschler and Bazilian, 2017; IMF, 2013a, 2014b). With the continuous enmeshment of SSA Governments with the electricity sector, the sector remains a major fiscal risk in the region.

A noteworthy case that encapsulates this is that of the electricity sector of Ghana. Between 2013 to 2016, there was an extensive load shedding in the country (dubbed "dumsor")[54] that triggered an immoderate procurement of new generation capacity over and above demand needs and at high prices. While the actual details of contracts remain unknown, available public information indicates that the GoG contracted three EPPs and the Electricity Company of Ghana (ECG) signed 15 thermal and 17 renewable energy PPAs through an uncompetitive procurement process. The result was costly excess thermal generation capacity of about 1.5 GW in 2020 and a corresponding capacity charge of about US$300 million annually (Ackah et al., 2021).

The sector regulator, in a strict execution of its mandate disallowed the costs of this excess generation capacity (referred to as idle generation capacity) in the tariff determination. These stranded costs, as well

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[53] Implicit liabilities represent moral obligations or burdens that, although not legally binding, are likely to be borne by governments because of public expectations or political pressures. *Contingent implicit liabilities* are not officially recognized until after a failure occurs. The triggering event, the value at risk, and the amount of the government outlay that could eventually be required are all uncertain.

[54] The load shedding was due to due to inadequate generation capacity, unavailability of fuel for existing power plants. Reduced hydrogeneration due to droughts, gas supply interruption from the West African Gas Pipeline (WAGP) and high prices of imported liquid fuels created the need to ration power in Ghana.

as other inefficiencies in the sector,[55] led to a fast accumulation of sector arrears as ECG struggled to cover the full cost of their power purchases. At the end of 2019, it was estimated that the accumulated stock of power sector arrears (legacy arrears) was about US$2.3 billion, with an annual revenue-cost margin of about US$1.3 billion, about 1.8% of GDP and about half of the annual GoG budget spending on social infrastructures. Subsequently, the Government launched the Energy Sector Recovery Program (ESRP) to serve as a roadmap to restore and sustain the financial viability of the energy sector (Ackah et al., 2021).

As part of the ESRP, the GoG passed the Energy Sector Levy Act in 2015 and the Energy Sector Levies Amendment Act in 2021 [56] to clear the legacy arrears and the annual sector shortfall respectively. It also earmarked about 1% of GDP (around $700 million) from the budget annually to support the programme until the sector is back in equilibrium. This was in addition to utilising about US$1 billion from bond issuance in 2020 (Eurobond) to rationalize the costs of the expensive PPAs to lower IPP capacity charges. Since the launch of the ESRP, the GoG has been making annual fiscal transfers of over a billion dollars to the sector (Ministry of Finance, 2020).

4.4. Distribution Cost Efficiency in Liberalised Small Systems

As mentioned earlier, the distribution segment accounts for about 25-30% of the cost of electricity supply on average. Distribution inefficiencies are often in the forms of poor operational performance and inadequate investments which lead to high technical and commercial losses, low collection rates and poor

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[55] In addition to poor investment decisions, the distribution companies (the ECG and Northern Electricity Distribution Company) in Ghana are also inefficient, with low collection rates, high losses, and weak governance. Distribution system energy losses averaged between 26% and 28.5% for the two distribution companies respectively, in 2020. Of the energy billed to the end-user, these distribution companies were only able to collect 70% of revenues, leading to further cashflow constraints. The COVID19 further impacted the power sector as the GoG announced a 3-month COVID subsidy to the power sector including a 50% subsidy for all and 100% subsidy for all lifeline consumers while ECG and NedCo announced a non-disconnection policy for non-paying customers until December 2020, resulting in an even lower collection rates during the period.

[56] The Parliament of Ghana passed the Energy Sector Levies Amendment Act, 2021 (Act 1064) to amend the Energy Sector Levies Act, 2015 (Act 899). The new amendment imposes an Energy Sector Recovery Levy of 20 pesewas per litre on Petrol and Diesel and 18 pesewas per kilogram on Liquified Petroleum Gas, and a Sanitation and Pollution Levy of 10 pesewas per litre on Petrol and Diesel to help pay the capacity charges in the energy sector as well as the fuel used by power plants to generate energy.

service quality. In fully deregulated sectors, distribution efficiency is typically incentivised through Private Sector Participation (PSP) and incentive regulation.

PSP experience in SSA has been limited over the years, with countries experimenting with various models thought to be best suited for various sector challenges. The longest lasting PSP arrangements in SSA till date have been in Nigeria, Gabon, Cote d'ivoire, Kenya and Uganda which are arguably more larger electricity systems. Generally, PSP in SSA involve contracts of whole utilities (distribution utilities or full vertically integrated utilities) through concessions, Management Service Contracts (MSCs), affermage contracts etc. with the goal of improving operational and commercial performance such as reducing energy losses (Aggregate Technical, Commercial and Collection – ATCC losses), improving corporate governance and in some isolated instances, reducing prices and service quality. In most cases, the responsibility of power purchasing is left to the Government or utility.

A success PSP story in SSA is the Société d'Energie et d'Eau du Gabon SEEG[57] concession in 1997, one of the earliest PSP experiences in SSA. Despite SEEG being one of the better performing utilities in the region, the Government believed there was further scope for efficiency improvements. The concession was heavily focused on operational performance, i.e., improving collections (especially of public sector bills which had reached about US$100 million) and reducing technical and commercial losses estimated at 17% at the time (World Bank, 1998). The concession had a strong political ownership, as evident in two key steps taken by the Government prior to the agreement, i.e., increasing electricity tariffs to cost reflective levels, and reducing the staff numbers at SEEG. Once this housekeeping had been completed, a competitive procurement for a 20-year concessionaire was launched aimed at improving service quality, expanding coverage at affordable rates, and ending the fiscal burden of the sector on Government (World Bank, 1998). However, the selection of the Concessionaire was based on a single bidding criterion, i.e., proposed percentage reduction in tariffs.

A consortium comprising the French Compagnie Générale des Eaux (currently Veolia AMI, France) and the Electricity Supply Board International (ESBI) of Ireland was selected, with a winning proposal of 17.5% reduction in tariffs. The Concessionaire had to invest a minimum of $135 million in rehabilitation (60% in water). It also informally committed to investing another $130 million in the sector over the concession period to increase network density and expand service. The Concession consortium also acquired 51% of SEEG and made an Initial Public Offering (IPO) for the remaining 44% of the company's shares with an exclusive offer of 5% to SEEG employees.

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[57] SEEG was a multisectoral utility which supplied water as well as electricity.

Within five years of the concession contract, more Gabonese gained access to electricity at no cost to the government and customer satisfaction with service delivery increased (World Bank, 1998). Financial performance of SEEG also improved, with dividends rising from the contractually guaranteed 6.5% of the share price in the first year of operations to 20% in 2000. Five years into the concession, 80% of the contractually required investments had already been made. The Government also began to pay its bills consistently after initial irregularities during the first two years of the contract.

The case of Gabon is evidently a reform success story in SSA with lessons for other small electricity systems. However, to place these lessons into better context, it is important to note that Gabon is one of the most affluent countries in SSA, an energy-rich upper middle-income country with abundant petroleum and renewable energy resources including hydropower. This made it easy for the Government to retain the responsibility of ensuring adequate generation capacity at low prices and implement pertinent but politically challenging reform steps such as increasing tariffs and reducing the overemployment of SEEG.[58]

Another important observation in the Gabon concession is the large investments in the networks secured in the contract. Generally, improvements in network efficiency and operational performance require major investments in network reinforcement and revenue protection programs. Without such investments, it can be challenging for most PSP models to achieve desired operational outcomes beyond improvements in collections. Subsequently, PSP models like MSCs which does not include obligations to make capital investments are generally ineffective in reducing technical and commercial losses although they can be useful in improving collections. However, as collection losses are often presented as part of energy losses, improvements in collection can create an impression of an improvement in energy losses.

A case-study that illustrates this is the Liberian electricity sector. Liberia is a small country in West Africa affected by fragility, conflict, and violence. By the end of the fourteen-year civil war in 2003, most of the Liberia's electricity sector infrastructures including the Mount Coffee hydropower Plant (the main generation source) and the transmission and distribution networks had been destroyed or looted. The Liberia

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[58] However, it is noteworthy that in 2018, SEEG's concession was terminated on allegations of deteriorated quality of service and complaints from consumers. As noted by the Gabonese minster of energy, "In the interest of preserving continuity and quality in the public provision of drinking water and electric energy, the Gabonese state has proceeded exceptionally to the temporary requisition of the company," Veolia had been accused of expropriating profits to shareholders in France at the expense of the necessary investments in the sector leading to a surge in energy losses from 12% in 2012 to 22.6% in 2018. They were accused of environmental breaches with respect to the delivery of their services. The termination of the contract made international headlines given the way the requisition of assets was done, described by Veolia as "brute force".

Electricity Corporation (LEC), which was the vertically integrated national utility also ceased operation during the crisis, leaving the sector non-functioning.

Following a peace treaty and a successful election in 2006, donor resources were mobilized to implement the Emergency Power Programs (2006-2012) which resulted in the installation of about 22MW of diesel generation, the reconstruction of some basic T&D infrastructures in parts of the capital - Monrovia, and the reestablishment of LEC operations to cater to the immediate needs of the country. The country has made modest progress since, with an installed generation capacity of 126 MW following the rehabilitation of the 88 MW Mount Coffee hydropower plant. However, investments in the network have lagged generation, making the current network capacity incapable of accommodating access expansion to the 93% of the population without grid access.

The Government of Liberia initiated reforms with the objective of increasing access to affordable, reliable, and sustainable energy. It has since enacted an electricity law and established a sector regulator which became operational in 2020. LEC has, however, been under a Management Service Contract since the end of the war because the civil war did not only destroy physical assets but also the human resources of the country.[59] These MSCs have nonetheless faced major challenges, with the current MSC struggling to address the high commercial losses in the sector. A major reason being that, since the rehabilitation of the Mount Coffee hydropower plant, demand for electricity connections increased sharply but LEC was unable to meet this new demand due to the constraints in the network and lack of funds. This resulted in a surge in illegal connections and subsequently in technical and commercial Losses which reached a staggering 63% by the end of 2020 (of which 15% is technical) from about 35% in December 2017. The Millennium Challenge Corporation notes the presence of a thriving cartel responsible for both petty and grand electricity theft (Mathematica, 2020).[60]

The high system losses, small customer base, and the relatively high general and administrative expenses of LEC have left the utility in a precarious financial position despite the high electricity tariffs of USc38.5/kWh and low generation costs from hydropower. With the high prices and the lack of revenue-protection mechanisms, existing customers including large consumers have begun to by-pass meters, initiating a vicious cycle of high prices and high losses putting LEC on the brink of financial collapse.

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[59] There was a two-year period during which there was an interim local management team while arrangements were being made to procure another MSC.

[60] See Smith (2004) for a comparative analysis of electricity theft.

In the case of Liberia, the financial viability of the sector and by implication the prospect to reduce prices hinges on the ability to reduce commercial losses. This requires large investments in access expansion, network reinforcement and densification to regularize illegal connections and connect consumers close to the current grid network. However due to a lack of business models for private investments in the networks, grid access expansion and network reinforcements projects are typically publicly financed in most SSA countries (Asantewaa et al., 2022; Jamasb and Marantes, 2011). Under such situations, the importance of a country's wealth becomes an important determinant of improved performance even if PSP is chosen as a management option as this determines the level of investments a government can make as well as the incentive to pilfer power.

In cases where distribution utilities remain under state management and or ownership, debt financing is used for these network investments. However, access to debt financing is limited for several utilities of small systems and for those that access these resources, the cost of capital can be very high given the poor financial position of several utilities. In most cases, equity injections by Governments (as the sole shareholder of the utility) are used to finance these capital expenditures. Subsequently, the capital dependency of SSA utilities on Governments remains high despite the liberalisation of the sector, and with the limited public financing available in most countries, these inefficiencies often reflect as high generation costs in most small systems.

An aspect of reforms that could be used to leverage private investments into the distribution and retail segments of SSA electricity systems is yardstick competition in distribution, which has interestingly not been pursued by several SSA electricity systems. As noted by Kuosmanen and Johnson (2020), inefficiency loss of a monopoly is not due to public or private ownership, but rather, due to lack of competition. Therefore, forcing local monopolies to compete with their peers will directly address the root cause of the problem. In the electricity sector, incentive regulation in general and yardstick regulation in particular is generally observed in fully deregulated electricity sectors, with the literature very simple and unassertive on whether the rules of yardstick competition can be modified to achieve a socially optimal allocation in alternative organizational structures such as vertically integrated sectors or horizontally bundled distribution segments.

In small electricity systems, discussions on the prospect of yardstick regulation are avoided altogether with efforts to improve distribution and retail efficiency often focused on incentive regulation by arbitrarily set regulatory standards or contractual benchmarks for single PSP franchises. Arguably, this is a very limited use of incentive regulation especially as there is no practical hindrance to yardstick regulation in these contexts given the evidence a much lower MES in the distribution segment (Yatchew, 2000; Giles and

Wyatt, 1993; Salvanes and Tjotta, 1998)[61]. In fact, larger utilities have been found to exhibit constant or decreasing returns while utilities that deliver additional services (46% of the utilities under study provide other services such as water/sewage) had lower costs, indicating the presence of economies of scope (Yatchew, 2000; Giles and Wyatt, 1993; Filippini, 1996, 1997).

Yardstick competition refers to the simultaneous regulation of homogenous firms with the rewards of a given firm dependent on its standing vis-á-vis a shadow firm, constructed from averaging the choices of other firms in the group (Shleifer, 1985). Firms in this virtual market is subsequently forced to compete with its shadow firm as the regulator uses the cost of comparable firms to infer attainable cost levels (Shleifer, 1985). Yardstick competition was the product of arguments that franchised monopolies (whether private or public) under cost-of service regulation have very little incentive to minimise costs especially as regulators are unlikely to know what the appropriate cost levels should be to justify any claims of inefficiency (Shleifer, 1985). Cost benchmarks or caps often used in PSP contracts in SSA for instance are also static, with no clear economic rationale for how this standard was determined. Thus, an alternative regulatory form is important to assure cost control, prevent waste, and promote cost-reducing innovation.[62]

Yardstick competition has been proven to not only be valid amongst homogenous firms facing identical demand conditions and price rules but also expected to outperform cost-of-service regulation even if heterogeneities are not accurately and completely accounted for (see Jamasb and Pollitt, 2001, 2003; Shleifer, 2020). What remained unclear was the viability of yardstick competition in vertically integrated electricity sectors. Mizuno and Okamura (1995) examined the effectiveness of yardstick competition under vertical structures in public utilities focusing on the relationship between its effectiveness and cost complementarities in the technologies of the constituent sectors of the industry. They concluded that yardstick rules can implement the first-best allocation if public-utility industries are vertically integrated.

There is a theoretical and empirical case for yardstick competition in liberalised small electricity systems, especially in SSA where benchmarks are often poorly designed and can incentivise regulatory games

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[61] Yatchew (2000) estimated that the MES in Ontario is achieved by utilities with about 20,000 customers with utilities which also participated in the delivery of other municipal services having costs that are 7 to 10% lower, suggesting the presence of economies of scope. Giles and Wyatt (1993) found output between 300-3500 GWh to be consistent with MES. Salvanes and Tjotta (1994) found the optimal size comprising utilities serving about 20,000 customers, independent of the level of GWh sold. Also see Salvanes and Tjotta (1998).

[62] Yardstick competition was originally used for a regulatory scheme in which private investor-owned firms are compared to public utilities.

(Jamasb et al., 2003, 2004). A recent study by Kuosmanen and Nguyen (2018) noted a spill over of the Averch-Johnson effect to the modern price cap and revenue cap regimes if the regulator defines the cap based on the observed capital input of the monopoly. In that case, a monopoly could increase the cap through its own investment decisions, creating an incentive to gold-plate. Thus, in several instances, these caps are at best superficial given the incentives and constraints faced by the regulated monopoly. Even if the regulator applies a stringent rate of return constraint to eliminate monopoly profit, the outcome will still fall short from the competitive market equilibrium. Kuosmanen and Johnson (2020) proposes conditional yardstick competition to address these issues of gold plating. This involves distinguishing between fixed and variable costs in the setting of benchmarking standards by treating capital as a fixed input, and local monopolies compete against the variable cost.

An important caveat for yardstick regulation to work, however, is for regulators not to allow an inefficient cost choice by a firm to influence the price and transfer payment that a firm receives (Shleifer, 1985). The regulator must be committed to enforcing its regulatory prerogatives to the point of bankruptcy of inefficient and imprudent firms to effectively enforce cost reduction standards. Shleifer (1985) recognizes the risk of collusive manipulation by regulated firms as a potential limitation of yardstick competition. However, this can be effectively managed as the number of firms participating in yardstick competition increases given the impracticality to coordinate and implement collusive agreements in high numbers and the private incentives to deviate from such an agreement (Shleifer, 1985). In addition, the regulator would be armed with a justifiable basis to mete out penalties for such collusive practices.

4.5. Conclusions and Policy Recommendations

This study examined electricity sector reforms in the context of small electricity systems. I presented the key challenges that emerge in liberalized electricity systems without markets and its implications for costs. I assessed the various regulatory tools and privatization arrangements that replaces competition and incentive regulation in liberalized small system, and how these have impacted costs and electricity prices. The analysis offers five main policy considerations for reforming small electricity systems relating to sector structure, procurement of generation capacity, incentive regulation, regional integration, and information sharing.

Sector Structure. I recommend continuous vertical integration of small electricity systems especially as many common problems in these systems are not differential to unbundling. Indeed, unbundling of small systems can create new problems relating to system coordination and information asymmetry between sector actors. Transaction costs to unbundle can be high, as new infrastructures and institutions will be required to support and manage new sector structures. While full vertical unbundling may not be necessary, accounting unbundling may be useful, especially if complemented by policy and regulatory actions that facilitate accountability and good corporate governance of utilities. Accounting unbundling can also help to identify and address inefficiencies in the sector. Such unbundling could include a clear delineation of boundaries between the Government in its various roles, as the representative of public sector interests, as the shareholder of the utility, etc. to avoid grey lines that breeds and nurtures inefficiencies.

Procurement of New Generation Resources. Focus should be placed on promoting value-for-money in the procurement of new generation capacity. While transparent competitive procurement based on an up-to-date Integrated Resource Planning can ensure this, full Government support is required to enforce these procurement standards. Government as majority shareholders of utilities in most small systems can require this. Also, while the generation segments of small systems may not be competitive, they can be contestable. This is especially the case with the emergence of new technologies in mobile power plants. Powerships for coastal countries and containerised solutions for landlocked countries are revolutionising how IPPs will be procured in the coming decades. With no sunk costs involved in their development, mobile power plants do not need and should not require long term take-or pay contracts or capacity payments. While their cost per kilowatt is high in several countries, these costs have been reducing significantly in recent years with new players such as Karpower. As more players come into the market, prices are expected to fall further. Small systems should thus seriously consider the development of procurement frameworks for mobile power plants to garner all contestable opportunities for lower prices.

Yardstick competition. Yardstick regulation remains a viable regulatory tool in small electricity systems. For several SSA countries, this model of private sector participation could be more attractive than traditional privatisation as it does not require a permanent transfer of assets to a singular private company. This model will also facilitate regulation by providing multiple sources of information for benchmarking. It would also be an effective way to increase investments in the distribution and retail segments i.e., network extension and densification in low access areas, network reinforcement to reduce losses and revenue protection programs to reduce commercial losses. However, these models require investments in boundary metering, smart metering, and other ICT ancillary infrastructures for real time information transmission to facilitate effective and credible competition which can be publicly financed or included in the design of such contracts.

Regional Power Pools. Regional power markets offer opportunities for small electricity systems to neutralise the scale limitations of their autarkic demand. However, full participation in these markets would require collective efforts at the regional level to remove the contractual rigidities of long-term “take-or-pay” contracts in the short and medium term. This could be achieved with contract for differences to cover the difference between the prices of PPA contracts and prevailing pool prices, financed by Governments of small systems as a transition strategy to facilitate a deeper participation in regional power markets.

Information Sharing. Small electricity systems can benefit from peer-to-peer knowledge and resource sharing and should consider forming a coalition to serve as a platform for such information exchanges. Such a platforms could be used to share information on costs of service delivery, generation costs opportunities and distribution performance standards. Such a platform would be a transparent, authoritative, and institutional source of information in the design of procurement standards and regulatory benchmarks. Over time, this coalition could also consider investing in shared infrastructures such as mobile generation facilities to provide access to cheaper generation resources during periods of unanticipated shortages.

5. Thesis Conclusion

5.1. Answers to Research Questions

Electricity sector reforms in SSA have altered in a very fundamental and irrevocable way the organisation of the sector, and along with it the incentives of market participants. The purpose of this thesis was to understand the nature of these changes and its implications for key electricity indicators including investments, technical efficiency, access, cost recoverability and utility financial performance.

In Chapter one, I presented the historical antecedents of reforms in SSA, recounting the factors that gave rise to the Structural Adjustment Programs in the 1980s. I told a story of how major economic events can be a catalyst for extensive structural reforms, especially in developing economies such as those in SSA. This story is particularly relevant today as policymakers are faced with another bout of stagflation following the immoderate spending responses to the COVID-19 pandemic by advanced economies, and the Russian attack on Ukraine which has destabilized global energy markets. Similar to the responses in the 1980s, several SSA countries are faced with macroeconomic challenges amidst high inflation and high crude oil prices. Under these conditions, countries in the region could be on the brink of major structural reforms as they look to international organisations to address economic challenges. The Russian attack on Ukraine has created new concerns about energy security and the need to reduce dependency on fossil fuels. This, together with the loud calls for climate action will put energy front and centre in the austerity measures that would be required of countries that would be approaching international organisations for support. Thus, it is a good time for SSA Governments to re-assess how such reforms have served them in the past to effectively negotiate the policies that would be considered in these engagements.

Chapter two assessed the performance of electricity sector reforms in SSA. With the use of parametric distance functions, I was able to show a positive correlation between reforms and installed generation capacity per capita as well as the plant load factor of SSA electricity system. This showed the effectiveness sector liberalisation in promoting efficient investments into the generation segments of SSA electricity sectors. However, the efficiency of networks was found to have deteriorated after reforms with observed increases in technical network losses suggesting the need for focused policies to promote investments in this segment. In testing the relevance of institutional features, I was also able to illustrate the negative correlation between perceptions of violent institutional features such as political instability and terrorism and reform performance, a finding that is particularly relevant in the worsening global fragility landscape.

In Chapter three, I explored the connection between reforms and electricity access. With the use of a production function and a SFA approach, I identified a positive relationship between successful reforms and the rate of electrification. Specifically, a unidimensional relationship between installed generation capacity per capita and electricity access rates was observed. However, the only reform step that corresponded to increase rate of access was the presence of a sector regulator while private sector participation and unbundling negatively impacted reform efforts. I also showed the relevance of demand-side factors in electrification efforts and the importance of a country's wealth in its electrification efforts.

In Chapter four, I explored the pathways to cost-efficiency in liberalised electricity systems without competitive markets using small electricity systems as a proxy. I brought an economic perspective to the emerging issues of poor financial performance of SSA utilities by highlighting the connection between reforms and costs. I presented the cyclical issue of cost-recoverability in SSA electricity sectors and provided policy guidance on how reforms should be approached in these contexts by leveraging mobile power plants, yardstick competition in distribution and participation in regional power markets.

5.2. Policy Implications

This study has shown the continuous relevance of reforms in SSA electricity systems decades after the completion of the SAPs. Reforms continue to be implemented in several SSA electricity systems but in a very stealth way. As it is not under the controversial brand name of the SAPs, few seem to recognise its origins and its goals. Reforms steps have come to represent a menu of policy options that policymakers choose from to address sector challenges without due consideration of its rationale.

Despite the bad press the SAPs faced in the ensuing years after its implementation, it is evident in Paper One that electricity sector reforms remain a potent and viable tool for several electricity sector problems in SSA especially in areas of investments. While it has not been as successful in facilitating investments into the network as it has been in generation, there is scope to develop viable business models for this purpose. While traditional reforms did not have provisions for that, it is an endeavour that should be pursued by SSA policymakers. On the institutional from, policymakers should work to improve perceptions about conflict, violence, and terrorist activities in the region as part of an integrated economic development program for a more sustainable development outcome.

From Paper two, it is observable that although reforms in SSA did not have an explicit electricity access component, its outcomes have implications for the rate of access expansion. I have shown a compatibility of sector liberalisation with access expansion indicating an opportunity to bundle reforms with access programs especially when a viable business model for private sector investments in the network has been identified. Energy efficiency has an important role to play in access expansion should be considered in an integrated access expansion program. The correlation between household consumption expenditure suggests an uncomfortable truth about how electricity access in SSA has been conceived in policy. Evidently, prioritising household access over productive use activities may be putting the cart before the horse. Thus, sustainable electrification programs should include income generation activities to ensure sustainability of outcomes.

Currently, the main challenge of most SSA electricity systems is issues of cost under recovery with electricity sectors emerging as a major drain on public resources and a fiscal risk. Paper 3 demonstrates the need for an economic and structural dimension to issues of cost-under recoverability in SSA electricity sectors through an intentional and explicit pursuit of cost efficiency in reform designs in SSA countries. Policymakers should leverage on all opportunities to enhance contestability especially in generation and distribution to improve and preserve the financial viability of their electricity sectors.

5.3. Policy Recommendations

The main policy recommendations by this thesis are as follows:

- A workable reform model in SSA involves vertical unbundling with an electricity law, a regulator and private ownership and management of electricity assets where desirable. However, as positive outcomes go hand in hand with an increase in technical network losses, policy emphasis should be placed on decoupling energy losses from power generation. This can be achieved through private sector participation and investments, with the private party compensated with part of the cost savings from the reduction in network losses.
- Policymakers in SSA should consider productive use programs and energy efficiency as key components of an integrated energy access programme. Electricity access programs should emphasize tiers of supply that supports productive use activities over lighting programs to avoid locking the poorest and most vulnerable into energy poverty.
- Rising inequalities increases the risk of violence, and this threatens the sustainability of reform outcomes. Thus, SSA Governments should ensure that sector reforms are inclusive and equitable through targeted subsidies for connections and subsistence consumption for the poorest and most vulnerable groups.
- Cost efficiency should be at the centre of reform designs in SSA, especially in electricity systems where the prospect of competition is limited. Policymakers should promote mobile power plants as an integral part of generation least cost development planning to facilitate contestability in generation. Government should remove rent-seeking opportunities in electricity sector procurement through transparent competitive procurement of new generation capacity to remove cost inefficiencies in the sector.
- SSA electricity systems should cooperate to improve the efficiency of the sector. Peer to peer knowledge sharing platforms would also be useful for SSA electricity systems to share information

on cost opportunities and possibilities to inform competitive procurement designs and the setting of benchmarking standards for regulation.

- SSA electricity systems should cooperate to compete through regional integration and power trade to neutralize the scale limitations of their autarkic demand. Regional markets could partner with national governments to develop contracts for differences to promote the full participation of all IPPs in regional power markets.
- Yardstick competition in the distribution segment remains viable in SSA electricity systems and should be pursued even in the absence of wholesale markets.

5.4. Limitations of the Study and Areas of Future Research

This thesis draws on extensive research and data collection which while not perfect, does have the merit of existing. It has some limitations with regards to the methodological approach used and data which constrained the depth of the analysis.

Data Limitations.

Electricity sector data in SSA is very limited and in most cases incomplete. This made it challenging to have an analysis that cover the most recent years as available public data is typically belated by about four years. In addition, available data is largely unbalanced, making reform performance scores an incomplete representation of the performance across the region. Some countries were excluded from the ranking due to unavailable data. In some of these cases, data was available at the country level, but differences in collection methodologies made it inappropriate for such panel data comparisons. More independent and timely data collection of electricity sector variables could enhance the quality of future studies.

Specific to Paper 2, electricity access data is obtained from the World Bank database. This data covers electricity access on all tiers, with no distinction on the level of tier being reported. This can be a problem as some electrification solutions involve assets that have a short asset life and could be unavailable after a couple of years. Thus, access data disaggregated by tiers will provide a more honest view of the electricity access situation across countries.

In the publication of Paper One of this thesis, an anonymous peer reviewer suggested the interpretation of the results using a Benefit-of-Doubt (BoD) approach. This approach helps determine the weights of sub-indicators of a composite indicator endogenously. As the reform performance score estimated in Paper one has several dimensions, it can be viewed as a composite indicator and the BoD can help assign weights to the various “sub-indicators” of reform performance, i.e., installed generation capacity per capita (gencap), plant load factor (plf) and reducing technical losses (losses). DEA is generally used to estimate BoD models given their conceptual similarities. Both share an objective of measuring the efficiency of an entity given observations on input and output quantities, no available information on prices, and no assumptions about the ‘functional form’ (or weighting scheme in the case of the BoD approach).

However, DEA is a nonparametric (linear programming) approach, which does not provide any information about the model parameters, i.e., reform steps and individual sub-indicators of performance, which is the primary goal of this study. Among alternative approaches, distance functions as proposed by Shephard (1953, 1970) are not only perfect aggregators and performance measures but also useful tools to represent the reform technology which has multiple policy inputs and objectives (Zaim et.al., 2001). Distance functions also share a similar conceptual starting point with DEA and subsequently BoD as it allows for the description of a production technology without explicitly specifying any behavioural objective (Lovell, 1996; Kumbhakar and Lovell, 2000; Coelli et al., 2005).

However, I understand and recognise that the use of dummies as “inputs” in distance functions raise some conceptual questions as conclusions made from this can be restrictive. Conceptually, our conclusions imply that one cannot scale up inputs (reform steps) to improve the outputs (outcomes). You either have the benefit of implementing it or you do not. While this may be a restrictive use of the potential of distance functions, we still believe that the policy implications from these results are important especially as the estimation is not inaccurate. With the value of information in the model parameters, it does take precedence in this study over the endogenously determined weights of reform performance sub-indicators. Unfortunately, I do not have a better methodology to achieve these dual objectives satisfactorily. However, this point raised by the anonymous reviewer presents some valuable insights. It demonstrates that SSA countries may have performed better on sector outcomes that were considered more important. Thus, future studies to determine policy priorities of SSA electricity systems using the BoD approach could be a useful extension of this study.

Paper three of the thesis could benefit from a quantitative assessment of post-reform cost levels in SSA. Unfortunately, panel data on electricity costs and prices is currently unavailable. In some countries, sector regulators publish periodic gazetted tariffs, but these publications are not consistent. Even in countries where these publications are more consistent, accompanying notes are not publicly available. I pursued this data collection, but it proved futile especially as I learnt the differences in accounting practices across utilities in the region. In fact, in countries with vertically-integrated utilities, accounts of the various segments are not vertically separated, making it challenging to disentangle the cost of each segment of the ESI. The World Bank is currently collecting such data in its Utility Performance and Behaviour in Africa Today (UPBEAT) project. Such data would be critical to expand Chapter three, which I plan to do once the data becomes publicly available.

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Appendices

Appendix 1: Status of Reform Implementation in Sub-Sharan Africa

Country	Year electricity Act was enacted	Year of Vertical Unbundling	Year in which an autonomous sector regulator was put in place	Years in which there was private sector management and ownership in the sector (Exclude IPPs).
Angola	2002	2014	No	2008
Benin	2007	No	No	No
Botswana	2008	No	No	No
Burkina Faso	2007	No	2007	No
Cabo Verde	2006	No	2003	2000 -2008
Cameroon	2011	No	2000	2000 till date
DR. Congo	2010	No	No	No
Cote d'Ivoire	2000	No	2000	2000 till date
Equatorial Guinea	2005	No	No	No
Eritrea	2004	No	No	No
Eswatini	2007	No	2007	No
Ethiopia	2000	No	2000	No
Gabon	2005	No	No	1996 - 2018
The Gambia	2005	No	2000	No
Ghana	2000	2000	2000	No
Guinea	No	No	No	2015-2017
Kenya	2000	2000	2007	2006 till date
Lesotho	2002	2000	No	No
Liberia	2009	No	No	2010 till date
Malawi	2002	No	2002	No
Mali	2000	No	2000	2000 till date
Mauritania	2001	No	2001	No
Mozambique	2000	No	No	No
Namibia	2000	No	2000	No
Nigeria	2005	2006	2006	2006 till date
Rwanda	2011	No	2001	No
Sao Tome and Principe	No	No	2005	2003 to 2006

Senegal	2000	No	2000	No
Seychelles	2012	No	2009	No
Sierra Leone	2011	No	2011	No
South Africa	2006	No	2000	No
Tanzania	2008	No	2000	2002 to 2006
Togo	2000	No	2000	2000-2006
Uganda	2000	2000	2000	2003
Zambia	2000	No	2000	No
Zimbabwe	2003	2003	2003	No

Note that some reform steps indicated to have been implemented in 2000 was implemented in 2000 or earlier.

Appendix 2.1 : Installed Generation Capacity per Capita of sub-Sahara African Countries (kwh)

	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Angola			0.03	0.03	0.03	0.04	0.04	0.06	0.05	0.05	0.06	0.06	0.06	0.06	0.08	0.09	0.10	0.15
Benin								0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.02	0.04	0.04	0.03
Botswana									0.08	0.08	0.08	0.08	0.08	0.07	0.30	0.29	0.29	0.34
Burkina Faso								0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.02
Cabo Verde	0.11	0.12	0.18	0.18	0.18	0.17	0.15	0.16	0.19	0.18	0.21	0.22	0.27	0.28	0.30	0.31	0.32	0.37
Cameroon	0.05	0.05	0.07	0.06	0.06	0.06	0.06	0.07	0.06	0.07	0.06	0.06	0.06	0.08	0.08	0.08	0.08	0.08
DR Congo											0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03
Cote d'ivoire	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.09
Eq. Guinea						0.05	0.05	0.07	0.07	0.07	0.08	0.08	0.34	0.32	0.31	0.30	0.29	0.44
Eritrea					0.06	0.06	0.06	0.06	0.05	0.05	0.04	0.04						
Ethiopia	0.01	0.01	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.03	0.02	0.02	0.02	0.02	0.04	0.04
Eswatini								0.13	0.14	0.14	0.14	0.15	0.17	0.16	0.17	0.17	0.17	0.17

Gabon	0.33	0.33	0.32	0.32	0.31	0.30	0.29	0.28	0.24	0.28	0.27	0.26	0.26	0.28	0.27	0.26	0.26	0.26
Gambia	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.05	0.06	0.06	0.06	0.06
Ghana	0.06	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.10	0.10	0.11	0.11	0.11	0.11	0.14	0.14	0.16
Guinea																0.05	0.05	0.05
Kenya	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.05	0.05	0.05
Lesotho	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Liberia										0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Malawi	0.04	0.04	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Mali	0.01	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05
Mauritania		0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.05	0.05	0.06	0.06	0.11	0.11	0.12
Mozambique	0.13	0.13	0.13	0.12	0.12	0.12	0.11	0.12	0.11	0.11	0.11	0.10	0.10	0.10	0.10	0.09	0.09	0.10
Namibia	0.21	0.21	0.21	0.21	0.21	0.20	0.20	0.20	0.23	0.22	0.22	0.18	0.23	0.22	0.21	0.21	0.21	0.21
Niger																	0.01	0.01
Nigeria						0.05	0.05	0.05	0.06	0.06	0.05	0.05	0.05	0.06	0.06	0.06	0.07	0.07
Rwanda		0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02
Sao Tome and Principe						0.09	0.09	0.09	0.08	0.08	0.08	0.12	0.12	0.12	0.11	0.13	0.13	0.14
Senegal	0.03	0.03	0.04	0.04	0.04	0.05	0.04	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.07
Seychelles										0.73	0.71	0.91	0.90	0.95	0.95	0.93	0.93	1.62
Sierra Leone												0.01	0.01	0.01	0.01	0.02	0.02	0.02

South Africa	0.88	0.87	0.86	0.87	0.90	0.89	0.89	0.88	0.88	0.89	0.88	0.86	0.85	0.82	0.87	0.85	0.86	0.93
Tanzania		0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.03	0.03	0.03
Togo	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Uganda	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Zambia	0.16	0.16	0.16	0.16	0.15	0.15	0.14	0.14	0.13	0.13	0.14	0.14	0.14	0.14	0.16	0.15	0.17	0.17
Zimbabwe				0.17	0.17	0.17	0.16	0.17	0.17	0.17	0.17	0.16	0.16	0.16	0.15	0.14	0.14	0.14

Appendix 2.2. Plant Load Factor of electricity systems of sub-Sahara Africa Countries from 2000 to 2017 (%)

	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Angola			38	43	39	34	43	30	39	44	42	41	45	60	51	43	40	27
Benin								15	13	10	13	11	9	5	11	10	8	10
Botswana									47	41	34	28	16	50	38	47	44	39
Burkina Faso								27	27	31	25	21	22	31	33	33	32	36
Cabo Verde	35	35	25	27	30	32	39	39	35	39	38	37	31	32	29	29	29	27
Cameroon	50	46	35	39	43	45	53	44	48	45	48	52	40	41	46	48	47	46
DR Congo											34	34	33	35	37	37	36	37
Cote d'ivoire	42	42	45	43	45	47	47	45	44	45	46	47	54	54	54	49	58	45
Equatorial Guinea						41	45	30	30	35	29	41	17	24	27	28	28	18
Eritrea					18	19	17	19	22	23	24	26	28	29	30	27	27	22
Ethiopia	22	21	11	12	11	13	14	16	18	20	26	30	36	42	46	50	34	37
Eswatini								38	31	38	41	46	39	37	34	30	22	25
Gabon	35	38	39	40	40	41	43	45	54	45	48	51	51	45	43	45	49	47
Gambia	33	56	53	53	51	51	50	48	51	43	37	39	38	3	2	28	29	27
Ghana	68	65	54	42	37	45	56	41	43	42	45	46	47	49	49	34	37	35

Guinea																23	30	31
Kenya	47	48	51	52	56	56	60	63	58	56	56	56	55	56	50	48	50	51
Lesotho	53	53	54	61	58	65	69	80	80	80	79	70	69	73	73	76	72	76
Liberia										26	22	21	21	21	21	21	20	19
Malawi	29	28	27	29	31	32	33	34	39	42	44	45	44	44	41	41	41	36
Mali	78	42	43	37	37	35	37	34	36	24	25	24	22	20	21	23	25	23
Mauritania		41	42	38	39	37	41	42	47	45	42	43	47	39	39	25	24	19
Mozambique	42	56	60	52	56	63	70	73	71	79	76	77	69	67	74	88	85	71
Namibia	42	36	43	46	40	46	43	49	51	43	36	47	35	40	35	35	33	38
Niger																	23	19
Nigeria						36	34	32	28	25	34	34	36	33	34	34	29	29
Rwanda		26	29	35	36	23	31	30	36	35	35	41	42	43	36	34	38	36
Sao Tome and Principe						33	34	36	38	42	46	30	34	34	37	34	36	34
Senegal	64	69	48	51	53	41	44	41	42	43	43	35	38	43	46	48	52	50
Seychelles										61	66	56	58	57	57	59	63	37
Sierra Leone												26	27	25	27	22	25	25
South Africa	57	57	59	62	62	62	63	65	64	60	62	63	62	62	57	57	57	52
Tanzania		74	80	51	37	45	41	50	50	54	54	53	58	61	64	54	65	64
Togo	26	15	21	27	23	23	27	21	18	22	21	18	20	17	18	22	50	34
Uganda	67	68	74	66	71	48	36	43	44	50	52	49	46	47	46	44	45	47
Zambia	51	52	51	52	54	56	63	62	61	64	62	65	70	73	66	64	46	55
Zimbabwe				47	52	51	44	40	40	38	45	49	49	51	55	53	40	42

Appendix 2.3 Technical Network Losses of sub-Sahara Africa countries from 2000 to 2017 (%)

	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Angola			15	15	15	15	12	14	11	11	12	12	12	12	12	12	12	12
Benin								16	16	21	19	19	19	20	20	20	21	21
Botswana									10	12	10	12	11	9	7	13	14	15

Burkina Faso								15	13	12	11	12	12	13	13	13	12	13
Cabo Verde	15	23	17	19	19	18	22	26	28	26	25	25	27	26	26	26	27	27
Cameroon	22	26	23	24	19	17	13	10	10	10	11	19	24	27	28	21	21	21
DR Congo	18	20	21	28	26	28	23	28	28	27	23	26	22	26	17	23	21	16
Cote d'ivoire	18	20	21	28	26	28	23	28	28	27	23	26	22	26	17	23	21	16
Equatorial Guinea						10	10	10	10	11	10	10	10	10	11	11	11	11
Eritrea					18	17	15	16	17	13	13	13	13	13	13	13	13	13
Ethiopia	10	12	11	11	11	11	11	11	13	15	20	21	19	15	19	19	19	19
Eswatini								12	12	13	12	11	12	12	12	12	12	12
Gabon	18	20	20	20	20	20	20	19	19	20	20	20	20	21	20	20	20	18
Gambia	22	22	22	20	19	22	22	22	21	21	22	20	21	21	19	19	19	22
Ghana	21	15	22	26	28	23	20	22	23	25	21	15	12	13	14	12	13	14
Guinea																12	10	10
Kenya	19	19	18	17	15	15	15	17	17	16	17	17	18	18	18	17	20	19
Lesotho	20	20	17	18	19	19	19	15	12	15	11	9	13	11	13	15	18	13
Liberia										8	8	13	13	13	13	14	17	17
Malawi	10	10	10	10	10	10	10	10	10	10	10	10	22	20	15	22	9%	25
Mali	10	10	10	10	10	10	9	10	10	5		5	5	5	5	5	5	6
Mauritania		4	3	3	9	9	9	18	16	17	18	16	15	17	17	16	16	17
Mozambique	20	21	22	16	16	15	18	19	19	20	19	1	17	18	17	30	17	15
Namibia	10	10	10	14	5	10	7	13	9	7	9	9	12	8	13	8	11	1
Niger																	18	16
Nigeria						21	21	15	15	15	15	15	15	15	15	15	15	15
Rwanda	27	27	27	21	27	26	11	14	15	15	17	17	20	16	20	20	20	
Sao Tome and Principe						31	30	29	28	28	27	26	24	24	20	16	15	14
Senegal	15	16	16	14	15	19	17	21	18	21	10	10	10	17	16	15	15	15
Seychelles										9	10	10	10	9	9	7	7	6

Sierra Leone												51	44	58	44	31	30	30
South Africa	9	8	7	6	6	9	9	9	9	10	10	9	9	9	9	8	9	9
Tanzania		25	23	26	20	27	26	22	19	35	20	22	18	19	18	17	15	15
Togo	6	15	14	14	13	15	14	17	17	16	17	16	15	16	15	14	14	9
Uganda	35	37	39	31	50	40	33	33	39	39	29	25	25	21	19	18	2	17
Zambia	4	4	4	4	4	6	7	13	22	20	19	24	8	10	17	12	15	10
Zimbabwe				12	13	13	11	12	11	16	18	17	19	17	17	18	17	18

Appendix 4: Efficiency Scores of Reform Performance SSA Countries (%).

	2000	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Angola		82	80	80	79	75	75	70	76	72	72	76	93	72	66	61	45
Benin							66	67	84	70	70	65	92	84	91	95	94
Botswana								78	79	67	70	58	77	63	92	93	92
B. Faso							57	56	59	52	50	53	62	65	66	65	71
Cabo Verde	76	74	51	54	58	81	86	86	97	96	96	92	92	91	86	89	85
Cameroon	8	63	67	68	69	79	66	73	68	74	81	75	80	90	84	83	84
DR Congo										39	43	37	38	74	64	60	59
C. d'Ivoire	80	91	94	95	97	93	96	95	92	90	93	96	97	93	92	95	
Eq. Guinea					71	71	65	65	70	66	73	52	59	67	68	68	46
Eritrea				90	86	77	83	84	69	73	73						
Ethiopia	42	28	30	28	31	32	34	38	43	53	56	59	59	64	70	44	45
Eswatini							80	72	83	84	93	84	81	78	69	57	62
Gabon	83	92	94	93	95	94	93	96	95	89	91	93	86	81	87	91	87
Gambia	72	93	95	95	94	95	94	94	91	87	87	87	81	74	75	79	78
Ghana	96	92	91	88	87	90	83	88	91	88	79	76	74	76	61	66	64
Guinea															58	62	63
Kenya	85	84	83	77	80	68	77	74	73	74	74	75	74	73	71	77	76
Lesotho	89	85	90	92	93	95	88	80	84	74	68	78	75	84	92	95	85
Liberia									54	43	56	56	57	57	60	65	64
Malawi	61	54	57	59	62	63	63	69	72	73	74	87	85	74	82	69	84
Mali	80	58	54	54	54	54	54	55	37	39	39	41	36	38	40	44	43
Mauritania		77	70	75	71	76	92	95	95	95	95	96	92	90	72	71	64
Mozambique	81	91	73	75	76	84	88	86	91	89	88	80	85	88	99	96	81

Namibia	84	81	88	68	82	74	88	86	72	66	83	67	70	71	63	64	71
Niger																55	55
Nigeria					63	60	52	49	49	55	53	55	53	55	53	51	48
Rwanda		62	55	55	48	53	52	60	64	64	64	68	71	68	72	76	72
Sao Tome					83	88	88	91	95	97	78	81	81	83	73	74	69
Senegal	98	93	93	94	91	90	92	90	95	83	73	78	93	95	96	97	96
Seychelles									94	97	82	93	91	93	94	96	52
S. Leone											94	88	97	86	76	77	77
S. Africa	80	83	86	92	92	96	96	95	93	95	95	94	94	89	89	89	82
Tanzania		95	82	63	75	70	90	82	96	87	88	87	91	94	88	94	95
Togo	42	45	52	47	53	53	58	54	56	59	54	57	55	53	57	87	68
Uganda	92	95	78	93	87	75	76	85	84	75	71	68	66	62	59	62	60
Zambia	74	74	73	76	79	86	88	94	94	90	95	89	92	87	81	64	67
Zimbabwe			86	91	93	80	77	78	85	94	94	95	94	96	96	85	90