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A Parametric Distance Function Approach

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ABSTRACT

Since the late 1980s, electricity sector reforms have transformed the structure and organisation of the sector in many countries across the world. While the outcomes of reforms in developed and some developing countries have been extensively examined, there is limited analysis on the outcomes of the reforms in sub-Saharan Africa (SSA). This paper analyses the performance of electricity sector reforms in 37 SSA countries between 2000 and 2017. We use a Stochastic Frontier Analysis approach to estimate a multi-input-multi-output distance function to assess the impact of reform steps and institutional features on sector-level performance. The results indicate that reforms in SSA increased the installed generation capacity per capita and plant load factor but did not reduce technical network losses. Also, the presence of an electricity law, sector regulator, vertical unbundling, and private participation in the management of assets have a positive impact on reform performance. Perceptions of non-violent institutional features such as corruption, regulatory quality and governance effectiveness do not seem to have significant effect on reform performance, but perceptions of political stability, violence and terrorism influence reform outcomes. The effects of hydroelectric capacity on reform performance was found to be negligible while larger electricity systems were found to be more efficient reformers. We conclude that a workable reform in SSA involves vertical unbundling with an electricity law, a regulator and private ownership and management of assets where desirable. However, the positive outcomes go hand in hand with an increase of technical network losses, and hence emphasis should be placed on decoupling these losses from generation capacity and plant load factor.

Keywords: Electricity Sector Reform; Sub-Saharan Africa; Institutions; Stochastic Frontier Analysis; Distance Function.

JEL classification: H54, O13, L94, P11, Q48.

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1. INTRODUCTION

During the 1980s, the electricity sector of sub-Saharan African (SSA) countries were beset with high subsidies, low service quality, high technical and commercial losses, price-cost margins, low access rates, capacity shortages and investment constraints (Newbery, 2002a, 2002b; Jamasb et al., 2014; 2017). Due to a global macroeconomic crisis the governments in the region needed to free up fiscal space and generate new sources of finance. The electricity sector was identified as a major drain on public resources, and a contingent fiscal risk given its persistent underperformance. The confidence in public ownership and management structures was weak and the virtues of market and private solutions started to be emphasised. This new direction was further propelled by traditional sources of finance for infrastructure projects (i.e., International Development Organisations), who indicated unwillingness to continue supporting persistent underperforming structures and called for market-oriented reforms as a key condition for financial support for future electricity sector projects (World Bank, 1993, 2003).[1]

The successes of pioneer reformers in other parts of the world including the US, Chile, Argentina, and the UK, which was manifested in improved financial performance of utilities, lower electricity prices, and expansion of choices available to consumers, encouraged other countries, including those in SSA, to implement reforms (Wolfram, 1999). This was buoyed by the 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 participation (Armstrong et al., 1994). These factors, together with the prospects of privatisation proceeds to amortise sector debts and restructure public liabilities, created a unique conjuncture to initiate Electricity Sector Reforms (ESR) in SSA.

Reforms aimed at introducing policies, regulations, and institutions that would unfetter the monopoly of state-owned utilities and provide avenues for private actors to participate in competitive markets (World Bank, 1993; Jamasb et al., 2014; 2017). The rationale was that unbundling of the traditional vertically integrated electricity utility would disentangle the vertical diseconomies in the Electricity Supply Industry (ESI). Then, liberalisation of the potentially competitive segments (generation and retailing) would facilitate new entrants, from the private sector, which would generate and sustain competition. It was indicated that competition would reveal the optimal generation level, mix and prices, leading to the release of previously constrained capital (Joskow and Schmalensee, 1983; Ennis and Pinto, 2002; Toba, 2007; Jamasb et al., 2005a).

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 internalise 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, 2001; Pollitt, 2012; Joskow and Schmalensee, 1983; Newbery, 2003b). These efficiency improvements are expected to be

[1] This directive was applied to all economic infrastructures. It was not limited to the electricity sector only.

passed on to consumers, directly through price and quality competition or indirectly through re-investment in new assets (Sen and Jamasb, 2012).

Reforms involved a set of steps or measures based on a model template (Jamasb et al., 2005a). These steps included (i) the enactment of an 'Electricity Law'; (ii) corporatisation and commercialisation 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 delivery and management of electricity assets (Bacon, 1999; Bacon, 1995; Bacon and Besant-Jones, 2001; Besant-Jones, 2006). However, given the diverse characteristics of electricity sectors globally, reformers were encouraged to review and select the options, mechanisms, and pace of reforms most appropriate to their needs and circumstances (World Bank, 1993).

The first wave of reforms in SSA focused on promoting investments into the electricity sector and improving the efficient use of labour and capital in the production process. This included expanding the generation base, increasing the load factor of generation plants, optimising the level of labour employment in the utility, reducing technical losses in the network segments, closing price-cost margins and promoting private sector participation in the delivery and management of electricity services. It had no provisions for poverty-related and environmental concerns and was widely criticised to be in the rent-seeking interests of private capital over considerations of social welfare (Joskow, 1998). Policymakers deployed specialised vehicles to tackle social issues (Estache et al., 2002; Carvalho et al., 2015). These programmes were typically run parallel to and were not always coordinated with the general reforms, and in several instances conflicted with the objectives of the core programme.

We examine whether reforms have been effective in delivering on medium-term objectives of ensuring capacity adequacy and improving the technical efficiency of the sector. We model the impacts of a set of reform steps taken during the first wave of reforms on core indicators of operational efficiency and investment promotion - i.e., net installed generation capacity per capita; technical network losses; and the load factor of generation plants. We use a Stochastic Frontier Analysis (SFA) approach to estimate a multi-input multi-output distance function using a data sample of 37 SSA countries from 2000 to 2017. This methodology is a move away from earlier studies, where a single performance indicator is modelled as a function of key reform steps and country-level (or firm-level) heterogeneities. To our knowledge, this is one of the earliest panel data empirical study on ESR performance for SSA as a region. It is also amongst the first analysis of reforms that captures the multifaceted nature of the programme and the trade-offs that exists amongst its objectives, thus providing a holistic assessment across countries and over time.

The remainder of this paper is organised as follows. Section 2 presents the literature review, with a combination of theory and empirical evidence. It reviews the reforms within a theoretical context and discusses empirical works on ESR performance in SSA. 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. LITERATURE REVIEW

In 1974, a high-profile antitrust suit by the United States Department of Justice filed against the American Telephone & Telegraph (AT&T) company raised some fundamental questions about how utilities are structured and managed.[2] The puzzle was whether effective regulation of the network segment of the ESI could coexist with conditions for effective and undistorted competition in generation and retailing segments, or whether 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 of all 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 Chile, the UK, Argentina, and Norway. It involved the restructuring of the ESI, liberalisation of the electricity sectors, and the creation of new regulatory methods and institutions (Armstrong et al., 1994). This was a move away from the traditional monopoly vertically-integrated ESI towards a deregulated sector which features competitive wholesale generation, free entry of new plants, unbundled transmission lines and distribution wires, regulated non-discriminatory tariffs, competitive supply markets and regulated trade across international interconnectors where possible (Pollitt, 2009).

Although the rationale for reforms was similar across countries, the context was remarkably different. In advanced economies, the electricity industries featured excess generation capacity, expensive technology choices, and inefficient production (Sen et al., 2018; Pollitt, 2009). In these countries, price trends, switching rates in retail competition and cost of regulation per unit of energy delivered were considered essential indicators of reform performance (Pollitt, 2009). On the other hand, in developing countries, there was a chronic shortage of capacity and the need for massive investments across the whole electricity supply chain (Bergara et al., 1997; Kessides, 2012). Electricity was unreliable, access rates were low, and utilities were financially unviable. Consequently, reforms in these countries aimed at amongst other things, increasing the level of investment in the sector, reducing capacity shortages, and reducing system losses, both technical and commercial (Pollitt, 2009). In these economies, additional constraints in the form of weak or non-existent regulatory institutions, political opposition to the economic pricing of electricity, the unattractiveness of revenues in local and often weak currencies, poor tariff collection rates and weak governance created additional challenges in the reform process (Pollitt, 2009).

With time, it became apparent that the complexity of reforms in the context of Emerging and Transition (E&T) economies such as those in SSA may have been underestimated. Moreover, issues of national and global interest pertaining to poverty reduction and climate change added new layers of complications to the reform process. It became apparent that the 'standard reform

[2] The Federal Communications Commission suspected that AT&T was using monopoly profits from its Western Electric subsidiary to subsidize the costs of its network, which was contrary to U.S. antitrust law (Yurcik, 2001). The United States Department of Justice filed the case in 1974.

model' may not be the first-best solution in these regions but rather a selective and phased approach to reforms could be useful. Consequently, a range of reform models have emerged across the region, featuring elements of the 'standard reform model' and remnants of the traditional sector organisation. These new models have led to the emergence of hybrid electricity sectors where elements of the traditional public ownership structures co-exist with private sector participation (Wamukonya, 2005).

In the following, we discuss the essential ESR steps typically featured in the reform process in SSA. We present this discussion in the context of underlying theoretical foundations and in the order of the preferred sequencing, i.e., legislation, regulation, restructuring, and private participation (Zhang et al., 2008; Besant-Jones, 2006). We subsequently review the primary objectives of reforms and some relevant empirical studies on how the programme has been able to achieve these objectives.

2.1 Key Elements of Electricity Sector Reforms

2.1.1. Legislation

The theoretical foundations of electricity sector reform and restructuring of the ESI can be found in the organisational economics literature. As explained by Coase (1960), in a world of positive transaction costs, legal rules matter for efficient outcomes. Consequently, ESRs are typically initiated with a legislative act that sets out the general framework for restructuring, private participation, and the establishment and role of regulatory bodies (Jamasb et al., 2005a). The act signals commitment to implementing reforms and reduces the uncertainty associated with property rights, contract resilience, and conflict resolution procedures (Guasch, 2004). It provides the necessary assurances to private investors and reduces the risk of regulatory taking (Fischer et al., 2000).[3] In SSA, the act also makes provisions for poverty-related programmes such as electrification and subsidy schemes and other important considerations such as energy efficiency and conservation, and renewable energy development.

2.1.2. Regulation

Traditionally, the policy-making functions and the regulatory functions of the electricity sector were performed by one entity. Reforms pursued the separation of these functions, advocating for policy formulation to remain with the state while regulation assigned to an autonomous sector regulator. Thus, following the enactment of the electricity law, an autonomous regulatory authority is established to have regulatory oversight over the reform process as defined by the Electricity Law. The importance of this statutory regulator is critical given the extensive empirical evidence of a strong correlation between the effectiveness of the regulatory agency and the progress and performance of reforms (Pollitt, 2009; Green and Trotter, 2005). 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.

[3] Regulatory taking is a situation when government regulation limits the use of private property to the degree that it effectively deprives the property owners of economically reasonable use or value of their property, even though the regulation does not formally divest them of the title to it.

Regulation is necessary because the network segments of the ESI (i.e., transmission and distribution) has natural monopoly characteristics, making the market an ineffective mechanism to deliver optimal outcomes (Joskow and Tirole, 2005; Arrow, 1970; Shubik, 1970).[4] Theory of economic regulation postulates that, an 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). Kay and Vickers (1990) classify regulation into structural and conduct regulation. Structural regulation focuses on market the 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). The sector regulator is charged to balance the interest of all market participants, safeguarding the high sunk costs of investors, and protecting consumers from monopoly exploitation. Public interest theory suggests that the relevance of regulation is not only in the context of imperfect competition, unbalanced market operation and missing markets but in the prevention and correction of undesirable market results (see 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 (see Kim and Mahooney, 2005). In SSA, this involves consumer safeguards especially in the areas of prices and quality of supply. Trade-offs can arise in 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, 2005; 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. Olsen et al. (2006) provides a comprehensive account of European Union (EU) 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 into 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 the stakeholders they are supposed to serve (Foster and Rana, 2020).

The efficacy of the electricity sector regulator is usually reflected in the competence with which it carries out its tasks (Pollitt, 2009). 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 such as benchmarking techniques to provide the

[4] 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).

appropriate incentives, especially for the non-price elements of performance such as quality of supply, energy losses, and investments.

2.2. Restructuring – Unbundling, Corporatisation, and Commercialisation

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 mitigate undesirable outcomes which may complicate subsequent adjustments to the process (Jamasb, 2006). Vertical unbundling often begins with the separation of the distribution business. This is necessary because many of the inefficiencies in the sector originate from the distribution activities, and not separating that segment could jeopardise potential gains from improving other parts of the ESI (World Bank, 2003). Following this, the distribution utility may be horizontally unbundled to provide enough firms for yardstick regulation. This is to ensure that the regulator is supplied with multiple sources of information for effective regulation (Jamasb, 2006).

Then, the transmission activity is separated, which is critical for promoting private participation in generation as it allows for non-discriminatory third-party access to the grid (Jamasb et al., 2005b; Joskow, 1998). However, this separation disrupts real-time coordination between the disaggregated segments of the ESI. Thus, to coordinate generation with the load, a system operator oversees the power scheduling and dispatching. Some reform scholars advocate for ownership unbundling of transmission (Hunt, 2002; Joskow, 2006a 2006b; Newbery, 1997; Littlechild, 2013; Hunt, 2002). However, given the institutional limitations of most SSA countries, it is recommended that the grid remains in state ownership (Jamasb et al., 2006). Nonetheless, the regulator should define the rules of grid access which should preferably be a 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., 2005a).

In order to facilitate wholesale competition, the generation segment may be split into several units to remove the dominance of the incumbent and create an adequate number of firms for a competitive electricity market. 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 ineffective to generate effective competition (Pollitt, 2009). The arguments for competition in the generation and the retailing segments of the ESI dwell on the ability of the market to stimulate both allocative and distributive efficiency (Armstrong et al., 1994). It is expected that in a competitive market, prices and profits would reveal valuable information on costs and provide the necessary incentives for firms to improve the efficiency of inputs use (Alchian, 1965; Green and Newbery,1997). The retail segment may 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.

Finally, the successor utilities are corporatized[5] 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).

2.3. Private Participation and Property Rights

The emphasis on private participation during reforms is underscored in property rights theories, which can be secured through the judicial system as well as the regulatory process. Property rights are believed to provide the necessary economic incentive system that shapes resource allocation. This is because private enterprises are driven by a desire for profits and may have more professional know-how in management, operating procedures, and use of appropriate technology (Guasch, 2004). It is expected that private entrants would create new production possibilities and efficiency improvements which could be captured and appropriated for the benefit of consumers (Demsetz, 1966, 1967, 1988). Furthermore, privatisation makes intervening in enterprise operations difficult for governments and politicians, so government manipulation is less likely (Guasch, 2004).

The general position is that public ownership is superior to private ownership under a few circumstances (Hart et al., 1997; Megginson and Netter, 2001). Earlier property rights theories were quite optimistic about its evolution toward economic efficiency. However, historical precedents have challenged these supposed welfare assertions of private ownership (see North, 1990a, 1990b). In the electricity sector, there have been several instances when privatisation did not deliver the anticipated technical efficiency gains (Jamasb et al., 2005a; Zhang et al., 2005; Estache et al., 2001; Freije and Rivas, 2003; McKenzie and Mookherjee, 2003). A notable example in SSA is the case of Nigeria which has undergone a full privatisation of their electricity sector since 2006, but significant inefficiencies continue to persist in the sector. On the other hand, Norway maintains government ownership and remains one of the well-functioning electricity systems (Jamasb, 2006).[6] With several of such examples globally, the consensus in the reform literature is that privatisation is not a necessary aspect of reforms (Jamasb, 2006).

Furthermore, ownership of electricity assets has some security implications due to its cross-cutting relevance to all aspects of the economy. Consequently, governments are typically reluctant to transfer the ownership of electricity assets to the private sector permanently. As a result, governments tend to lean more towards forms of private participation which does not require the permanent transfer of property rights to the private sector. As explained by Foss and Foss (2001), the ownership of an asset is not ownership of the physical asset per se, but

[5] Corporatisation is the process of 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 also 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.

[6] 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.

ownership of specific economic rights to that asset or specific aspects of it (also see Coase, 1960). Innovative Public-Private Partnership (PPP) models have made it possible to mobilise the private sector in new and existing electricity sector businesses without necessarily having to relinquish ownership. These new models are typically in the form of management service contracts, *affermage* contracts or concessions (World Bank, 2003).[7] 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 privatisation is desirable and feasible, it would ideally start with the distribution networks, as this enhances private interest in the sector and signifies a commitment to instil commercial discipline across the industry.

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

Institutions have been indicated to play an important role in public policy. 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 (World Bank, 2003). Consequently, the sector transformation process and its outcomes at each stage is very fragile and highly susceptible to the local political economy.

In many E&T countries like those in SSA, reforms take place within institutional settings that are characterised by unstable political systems, interventionist governments, unclear legislation on property rights, limited accountability, lack of judicial credibility and corruption (Jamasb, 2006; Laffont, 2005). During the reform process, it is therefore imperative that governments demonstrate political and legislative leadership and sustained commitment to regulatory and institutional changes. On the other hand, policymakers need to make realistic assumptions during reform formulation to ensure that the regulatory framework is in line with the institutional attributes of the country (Levy and Spiller, 1994; Bergara et al., 1998).

The impact of institutional quality on the performance of utilities has emerged in various performance analysis (Imam et al., 2017a, 2017b; 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 among other issues, and governance as how credible commitments are generated. Ghosh and Kathuria (2016) explain that while the earlier emphasis of the regulatory literature has been on incentives (Loeb and Magat, 1979; Laffont and Tirole, 1993), the new institutional economics is concerned with governance (Tommasi, 2006; Tommasi and Velasco, 1996).

The tenets of the 'economics of governance' stems from Noll (1989) and other related works such as Stern and Holder (1999), North (1990a, 1990b) and Levy and Spiller (1994). These studies emphasise the set of devices that are used to bring order into transactions through well-defined property rights, contracts and other enforcement mechanisms.[8] Kraay et al. (1999,

[7] See the World Bank PPP database for more details on the various forms of public-private partnerships.
[8] See Dixit (1996) and North (1990a, b).

2003, 2009) provide a more detailed and broader definition of governance, describing it as the traditions and institutions by which authority in a country is exercised. These include: i) the process by which governments are selected, monitored and replaced, ii) the capacity of the government to effectively formulate and implement sound policies, and iii) the respect of citizens and the state for the institutions that govern economic and social interactions among them. Kaufmann et al. (1999) explain that governance is not randomly distributed across countries, but good governance requires time and resources to develop. The study further iterates that wealthier countries are more likely to enjoy good governance. Mahoney (2004) adds that good governance is also a function of a country's political and social history, especially in those countries that inherited a set of institutions from former colonial powers.

In many developing countries, the prevalence of economic corruption and political opportunism is a significant source of inefficiency in the electricity sector, generally at the expense of the poor (World Bank, 2003). These tendencies emanate from high stakes in reform transactions and the plentiful opportunities for rent-seeking (Olson, 2006). Political opportunism may take the form of gaining political scores with constituencies especially in tariff restructuring. In liberalised electricity sectors, the quality of the regulator has been indicated to be a good reflection of the institutional capacity or governance capabilities of the industry (Cubbin and Stern, 2006; Ghosh and Kathuria, 2016). Estache and Wren-Lewis (2009) identify regulatory capacity, commitment, accountability, and fiscal efficiency as key institutional aspects which affects regulation in developing economies. This is particularly important in the SSA context where reforms depart significantly from the model frameworks in countries' energy strategies. 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).

In addition to these institutional considerations, there are factors outside the electricity sector that may affect reform processes and performance. A notable factor is the size of the electricity system which has been indicated to constrain the effectiveness of market-based reforms. Some studies have suggested the benefits of a full reform package may be small in relation to the costs in small electricity systems as the case for unbundling the sector gets weaker as the system becomes smaller (Besant-Jones, 2006; World Bank, 2004; Hunt, 2002). Also, given that reforms occur within the broader economy, a range of macroeconomic and exogenous factors including access to international financial market, interest rates, exchange rates and inflation could affect reform implementation and performance. Limited access to the capital markets and high interest rates dissuades international investors from investing whereas high inflation rates in reforming countries makes contracts in local currencies unappealing.

With the increasing share of thermal plants in the generation portfolio, fuel costs have become a major part of operating costs. High fuel costs have been found to hamper the ability of utilities to recover their costs as tariffs are generally slow to adjust to these changes and government transfers may be required to bridge the price-cost margins. Ideally, these risks are mitigated with automatic-adjustment pricing formulas which allow for self-activating pass-through for indexed costs. However, in several SSA countries, pricing is ad hoc and the lead times between changes in costs and price adjustments can be significant. In such instances, price signals may be ineffective in influencing investment and consumption decisions.

Another factor that have been indicated to affect the electricity sectors of SSA countries is hydrological factors. Over the years, several countries have experienced significant drought as a result of climate change. Koch et al. (2016) indicates that to this may lead to a decrease in discharge and water availability and a subsequent a decrease in hydroelectric power generation. In a simulation analysis, the study found that a significant decrease leads to a reduction in hydroelectric power generation of 9-16 % in the sub-basins (Koch et al., 2016). As at the end of 2018, the International Hydropower Association estimated that Africa had about 36,264 MW of installed hydroelectric generation capacity representing over 20 percent of installed generation capacity (International Hydropower Association, 2020). Thus, hydrology is an important aspect of SSA electricity systems and their performance (Cole et al., 2014; Blimpo and Cosgrove-Davies, 2019).

2.5 Reform Performance

Jamasb et al. (2005b) identify several approaches for evaluating ESR performance: 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 practices (Jamasb et al., 2005b). Case studies, which are typically conducted at macro (country) or micro (household or firm) levels are suitable when an in-depth investigation and qualitative analysis are required.

In SSA, the principal push-factor for ESR was the urgency to transfer the investment burden onto the private sector. This involved stimulating investments in new capacity to broaden the generation base and refurbishment of existing assets to increase the load factor of plants and reduce the level of technical network losses. Thus, the first wave of reforms focused on improving Technical Efficiency (TE) which was noted to be compatible with all other objectives (Wolfram, 1999; Pestieau and Tulkens, 1993). The consensus is that, utilities of countries that reformed their electricity sectors performed better in terms of TE than those that did not, predicated on the combination and in some cases the sequencing of reform steps (Zhang et al., 2005).

Plane (1999) for Côte d'Ivoire evaluated the impacts of the privatisation of the vertically integrated electricity utility defined by a ten-year management contract on TE. The study utilised 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 TE improvements after signing the contract although the performance was irregular over the period. However, the results also indicated that TE never reached the levels of the 1970s when the company was under close government supervision.

Estache et al. (2008) utilised 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 TE in the region 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 utilised 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 ESR on plant load factor and network losses after controlling for country-specific variables such as GDP.

There are arguments that the TE issues in the electricity sectors of SSA countries are but manifestations of financial inefficiencies pertaining to electricity pricing and prices. The logic for this assertion is that a utility without good cash flow cannot afford to maintain existing assets or make new capital expenditures. For utilities to achieve a good financial position, electricity prices must reflect the long run marginal cost of production and delivery as well as market risks and inflation (Haselip and Potter, 2009; Jamasb et al., 2014). In SSA, under-pricing and revenue inadequacy have been pervasive, and prices seldom reflect actual costs (Kessides 2012). Approximately two-thirds of the utilities in the region set tariffs high enough to cover operating costs while only a fifth of these utilities charge prices high enough to cover their full capital costs and depreciation (Foster and Briceño-Garmendia, 2010).

An International Monetary Fund (IMF) survey measured the difference between the actual revenue charged and collected at regulated electricity prices and the revenue required for full recovery of operating costs of production and capital depreciation. This provides a 'quasi-fiscal deficit' for the electricity sector, reflecting the level of government intervention in electricity pricing. The survey finds this quasi-fiscal deficit ranges from 0.3% as in Chad to 7.2% in Mozambique.[9] The median quasi-fiscal deficit for the entire SSA region was estimated around 1.7%. This means that electricity tariffs are about 1.7% lower than what would be required for full recovery of operating costs (IMF, 2013a). Eberhard and Shkaratan (2012) indicated that utilities in SSA capture only two-thirds of the revenue they need to function sustainably. By setting tariffs below the levels needed to cover actual costs, SSA countries forego revenues of at least \$3.62 billion a year, equivalent to 0.56% of the region's GDP per 2011 estimates (Eberhard and Shkaratan, 2012).

The publicly articulated rationale for this expensive interference is that, pricing electricity at these levels foster some desirable welfare goals by offering some degree of social protection for consumer groups who would otherwise be disadvantaged (World Bank, 2009). The longer these subsidies have existed in a country, the more entrenched it is and the stronger the opposition to remove them. This is worse in cases where benefits of these subsidies have been capitalised, e.g., by the adoption of power intensive technologies and equipment in businesses (IMF, 2013b). In the few instances when utilities have increased tariffs to reflect costs, it has been politically difficult to maintain. Prices have ended up been rescinded or allowed to be eroded by inflation (Smith, 2004). In the short to medium term, the removal of such subsidies

[9] A lower quasi-fiscal deficit indicates lower interference in pricing and vice versa.

may result in economy-wide loss of competitiveness and may exert upward pressure on inflation (IMF, 2013b). Consequently, welfare considerations, especially for the poor, inhibit governments' commitment to removing these subsidies and implementing reforms in SSA (Fankhauser and Tepic, 2007).

However, this practice has initiated a vicious cycle of underinvestment, poor maintenance, and inadequate supply. Electricity subsidies have been criticised for being a poorly targeted and regressive policy although their removal may adversely affect the poor if there are no appropriate compensating measures (IMF, 2013a). However, the net benefits of setting electricity tariffs to reflect costs, coupled with a reallocation of some or all subsidies are more pro-poor given the broader social and economic benefits of a financially viable electricity sector (Foster et al., 2017; Komives et al. (2007). Notwithstanding, several countries are reluctant to remove electricity subsidies because the status-quo favours the few better-off urban consumers (rather than the poor) with resources to mobilise against the government and manipulate policies to their benefit (Estache and Rossi, 2004; IMF, 2013a).

Also, large volumes of electricity produced in SSA are lost to power thefts and non-payments. In order to ensure the financial viability of the sector, these costs must be appropriated and recovered, nonetheless. This puts the electricity sector regulator in a dilemma of who should bear the incidence of these costs. If the corresponding charge is added to the cost of supply, paying customers are penalised for the inability of the utility to enforce commercial discipline while not factoring those stranded costs into tariffs would make the utility financially unviable (Victor, 2005). Typically, the regulator places this burden on customers and gradually transfers it to the utilities through some benchmarking incentives (World Bank, 2005). In certain instances, the utilities may charge a customer group higher prices to cross-subsidise another group while in other cases the government claim responsibility of these price-cost margins (IMF, 2013a).

With a broad disparity between electricity prices and costs in SSA, the general expectation that new entrants with more efficient technologies would ultimately put a downward pressure on prices in the medium term is thwarted, and often deferred to a longer term. Rather, electricity prices have risen in most SSA countries after reforms and are amongst the highest in the world (World Bank, 2017).[10] There are isolated cases such as that of Namibia and Côte d'Ivoire where private participation in the sector improved billing and reduced commercial losses resulting in actual tariff reductions (Plane, 1999; World Bank, 2005). However, there has been a contention about the actual cause(s) of these price falls, especially in low-income groups based on arguments that targeted subsidies could have produced these results (Paredes, 2001).

[10] See Balza, Jimenez and Mercado (2013) and Haselip and Potter (2009) for how electricity prices increased in other transition economies outside SSA.

3. METHODOLOGY

3.1 A Stochastic Distance Function to Measure Reform Performance

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 optimise, not all are successful in doing so. OLS delivered estimates of models in which the 'average' rather than the 'best-practice' behaviour of producers were 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 theorises 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, Seiford and Tone, 2007). Frontier approaches may be parametric in nature, as SFA; nonparametric such as DEA; or even semi-parametric such as the Stochastic Nonparametric Envelopment of Data (StoNED) proposed by Kuosmanen and Kortelainen (2012).

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.[11]

When multiple outputs are produced using multiple inputs, Shephard (1953, 1970) distance functions provide a functional characterisation of such 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).

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

We utilise an output distance function to estimate the efficiency with which SSA countries have translated reform steps and some institutional features into sector-level performance.[12] If we define a vector of inputs as $x = (x_1, \ldots, x_K)$ and a vector of outputs 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, we can then specify a feasible multi-input multi-output production technology using the output set $P(x)$ that can be produced using the vector of inputs, 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), an output distance function can be defined as:

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

where φ represents the minimum scalar by which all the outputs can be proportionally divided while remaining in the feasible production set. Färe and Primont (1995) demonstrate that the output 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 $0<TE\leq1$. Consequently, when a firm is operating on the frontier, it has a distance function value equal to unity and consequently has a technical efficiency score of 1.

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

$$\begin{aligned}\ln D_{Oi}(x, y) = \alpha_0 + \sum_{m=1}^{M} \alpha_m \ln y_{mi} + 0.5 \sum_{m=1}^{M} \sum_{n=1}^{M} \alpha_{mn} \ln y_{mi} \ln y_{ni} + \sum_{k=1}^{K} \beta_k \ln x_{ki} \\ +0.5 \sum_{k=1}^{K} \sum_{l=1}^{K} \beta_{kl} \ln x_{ki} \ln x_{li} + \sum_{k=1}^{K} \sum_{m=1}^{M} \delta_{km} \ln x_{ki} \ln y_{mi}, \quad i = 1, \ldots, N\end{aligned} \tag{2}$$

where α, β and δ are parameters to be estimated, i indicates the ith observation in the sample and all the 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 normalising the output distance function by one of the outputs arbitrarily chosen, e.g., y_M. This transforms equation (2) into the following expression:

[12] 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).

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

$$+0.5 \sum_{k=1}^{K}\sum_{l=1}^{K} \beta_{kl} \ln x_{ki} \ln x_{li} + \sum_{k=1}^{K}\sum_{m=1}^{M-1} \delta_{km} \ln x_{ki} \ln\left(\frac{y_{mi}}{y_{Mi}}\right), \quad i = 1, \dots, N \quad (3)$$

After rearranging terms and expressing the translog specification as TL, the function can be rewritten as:

$$-\ln(y_{Mi}) = TL\left(x_i, \frac{y_i}{y_{Mi}}, \alpha, \beta, \delta\right) - \ln D_{Oi}(x,y) \quad (4)$$

where $-\ln D_{Oi}(x,y)$ represents the radial distance from the boundary, i.e., deviations from optimal production levels. We set $-\ln D_{Oi}(x,y)$ as equal to u which represents the inefficiency term, and we add a noise term, v, to capture statistical noise. This transforms equation (4) into a model with a composed error term in which we assume v is a normally distributed random error term and u follows a half-normal distribution.[13]

We consequently obtain the following equation:

$$-\ln(y_{Mi}) = TL\left(x_i, \frac{y_i}{y_{Mi}}, \alpha, \beta, \delta\right) + v + u \quad (5)$$

In this paper, we are also interested in identifying sources of inefficiency in the process of transforming reform steps into electricity sector 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 the study of determinants of inefficiency. Estimates from such models can yield biased estimates of both frontier coefficients and firm-specific inefficiency scores (Caudill and Ford, 1993). This issue can be addressed using a heteroscedastic frontier model that allows to incorporate variables as efficiency determinants. Here we include generation capacity, hydroelectric capacity, control of corruption, the presence of a regulator and private participation as determinants of the inefficiency in the model through the pre-truncation variance of the inefficiency term, u.[14]

[13] For estimating the model, we need to make some assumption 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).

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

4. DATA

We utilise a dataset that comprises of an unbalanced panel of 37 SSA countries[15] from the year 2000 to 2017. These countries are those that 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.

We also include private participation in operations and management of the sector as a control variable based on the rationale that private participation is often the product of effective sector liberalisation. All these variables are dummies that take value 1 in case the reform step (or private participation) has been implemented, and 0 otherwise. Table 1 summarises the details of these variables.

Reform Steps (Inputs)	**Description**	**Descriptive Statistics**
Electricity law ***act***	The presence of a law that initiated reforms (initiated sector liberalization).	Max = 1 Min = 0 Mean = 0.87 St. Dev. = 0.33
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
Control Variable		
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 PPP arrangements only.	Max =1 Min = 0 Mean = 0.26 St. Dev. = 0.44

Table 1: Description of reform steps (Inputs) and privatisation (Control Variable)
Source: Compiled by the authors

[15] 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.

We consider three performance indicators as outputs. 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 electricity sector and the technical efficiency of assets in all segments of the ESI, as per the aim of the core reform program. Table 2 provides the details of the output 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).[16] It is measured in percentage.	Max= 0.58 Min= 0.032 Mean= 0.07 Std. Dev.= 0.16

Table 2: Description of performance indicators (Outputs)
Data Source: United Nations Database

Control Variables and Inefficiency Determinants

In recognition of the important role of institutions on policy effectiveness, we also included the Regulatory Quality, Governance Effectiveness, Control of Corruption and Political Stability and Absence of Violence and Terrorism dimensions of the WGI in the model as control variables.[17] Control of corruption variable was included as a determinant of inefficiency, while the other three were included as control variables in the frontier. We also include the level of hydroelectric capacity (MW) in the generation portfolio as a control variable to capture the contribution of hydropower to sector performance and as an inefficiency determinant. In order to assess the impacts of the size of the electricity sector on performance, we also include the installed generation capacity in the country in the model as an inefficiency determinant. In addition, we included the presence of a sector regulator and private participation variables as inefficiency determinants to explore potential impacts of regulatory risks and private sector participation on efficiency. Table 3 summarises the control variables.

[16] We note that there are several databases that 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 overestimation of the actual technical losses.
[17] These are dimensions of the six World Bank Governance Indicators (WGI).

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
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.		

Table 3: Description of Institutional Variables and other sectoral characteristics (Control Variables)
Data Source: World Bank and United Nations Databases

5. RESULTS AND DISCUSSION

Production theory assumes that output-oriented distance functions should satisfy the curvature and monotonicity conditions previously described.[18] As a direct consequence, we expect the coefficients of inputs (β) to be negative and that of outputs (α) to be positive for this type of distance function.[19] These coefficients can be interpreted as distance function partial elasticities with respect to outputs and inputs 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, we expect the coefficient of the *losses* variable to be negative and the coefficients of *plf* and *gencap* to be positive.

Table 4 presents the parameter estimates of three specifications of the output distance function utilised 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. We present the results of all the model specifications but only discuss the results of the translog model with inefficiency determinants since this latter model is the preferred one.[20]

As can be seen in Table 4, the estimated first order coefficients of the performance indicators, i.e., *losses* and *plf*, are positive and statistically significant, while *gencap*'s computed coefficient also has a positive sign. The positive coefficient of *gencap* indicates that reforms have increased investments in the generation segment of the ESI 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 (2019). Eberhard et al. (2017) explains that electricity sector investments in SSA picked up in the early 2000s, with IPPs and Chinese funded investments[21] accounting for over 13.8 GW of generation capacity in the region as at the end of 2016 (Eberhard et al., 2016).[22]

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

[19] The parameters of the model are estimated using the maximum likelihood procedure. As we 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.

[20] We 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 we consider the latter our preferred model.

[21] 49% of Chinese investments in the power sector appear between 2010 to 2020 was in hydroelectricity (International Energy Agency, 2016).

[22] It is important to note that an increase in the rate of installed generation capacity per capita does not necessarily assure capacity adequacy as rate of increase in demand could be higher than the rate of increase in population due to higher consumption per capita.

Variable	Cobb-Douglas		Translog		Translog w. Inefficiency Determinants	
	Coefficient	***Std. Error***	***Coefficient***	***Std. Error***	***Coefficient***	***Std. Error***
Frontier						
Outputs						
log (*gencap*)	<u>0.10</u>		<u>-0.02</u>		<u>0.02</u>	
log (*plf*)	0.51***	0.03	0.49***	0.08	0.58***	0.08
log (*losses*)	0.39***	0.05	0.53***	0.07	0.40***	0.07
Inputs						
act	0.03	0.03	-0.23***	0.08	-0.24**	0.08
unb	-0.14***	0.04	-0.41**	0.21	-0.48**	0.18
reg	0.01	0.03	-0.29***	0.09	-0.37***	0.09
Control Variables						
pi	-0.14** *	0.03	-0.12***	0.02	-0.22***	0.04
rq	-0.04	0.04	0.02	0.04	0.05	0.03
ge	-0.08	0.05	-0.03	0.05	-0.04	0.05
ps	-0.06***	0.02	-0.07***	0.02	-0.09***	0.02
hydro	-0.01***	0.01	-0.01 ***	0.01	-0.01 ***	0.01
Output Interactions						
0.5 (log *plf*) ^{2}			0.26***	0.06	0.21***	0.05
0.5 (log *losses*) ^{2}			0.27***	0.04	0.23***	0.04
log (*plf*)* log (*losses*)			-0.31***	0.04	-0.27***	0.04
Input Interactions						
*act*unb*			0.34*	0.20	0.36**	0.17
*act*reg*			0.23***	0.08	0.25***	0.08
*unb*reg*			0.04	0.09	-0.08	0.09
Inputs-Outputs Interactions						
(log *plf*)**act*			-0.14**	0.06	-0.25***	0.08
(log *plf*)**unb*			-0.17*	0.09	-0.14*	0.09
(log *plf*)**reg*			0.28***	0.05	0.28***	0.05
(log *losses*)**act*			0.06	0.05	0.16***	0.06
(log *losses*)**unb*			0.12	0.07	0.08	0.08
(log *losses*)**reg*			-0.31***	0.04	-0.29***	0.04
intercept	-0.34***	0.04	0.05	0.09	0.16	0.09
Noise Term						
log (σ_v^2)	-5.07***	0.32	-5.49***	0.34	-5.60***	0.31
Inefficiency Term (variance)						
intercept	-1.64***	0.09	-1.90***	0.09	-3.45***	0.27
log (*gc*)					-0.46***	0.10
pi					0.88***	0.21
hydro					0.01***	0.01
reg					0.63***	0.22
cc					-0.22	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.

Table 4: Parameter Estimates

The positive and significant coefficient of the *plf* variable indicates that the post-reform electricity generation portfolios in SSA countries have a higher load factor than the pre-reform portfolio. This finding can be explained by the increasing share of CCGT and open cycle technology plants in the generation portfolios of SSA electricity systems. These power plants are not only modular, but are also more efficient, with a higher firm capacity. As at the end of 2017, over 84% of installed power capacity in SSA was from thermal sources (CCGT and Open cycle technologies). In addition to these favourable technological features, the incentives structure of power purchasing contracts with IPPs promotes the optimum utilisation of plants.

However, the positive sign of the coefficient of the *losses* variable is contrary to what should be expected for a "bad output" in an output distance function. This indicates that reforms resulted in an increase in the rate of technical network losses. This finding is however not surprising given that the initial reforms did not have adequate provisions for promoting investment in the network segment of the ESI. There continue to be a lack of appropriate business models to garner and sustain private interest in investing in electricity networks especially in SSA. The concept of Independent Power Transmission is being explored but reservations about the institutional capacity of SSA countries to deliver such business models remains (World Bank, 2017). As result, electricity network infrastructure in SSA have become old and obsolete. Given that most countries in SSA are developing countries, demand growth in the region has been increasing exponentially over the years due to increased economic activity and access expansion, and the increasing load in the dilapidated networks have resulted in increasing technical network losses.

With respect to the inputs, we find that the first order coefficients of *act*, *unb*, and *reg* are significant at 1% significance level and with the expected negative sign of output distance functions. The significance of the coefficient of the *act* variable indicates that the existence of an electricity law which legitimizes the liberalisation of the sector is an important input in reform performance. This indicates the importance of a favourable legal framework for reforms.

The significance of the coefficient of *reg* indicates the importance of an autonomous sector regulator. This finding highlights the critical role of independent authority in sector reforms, as an administrator of electricity tariffs, and holding the mandate for negotiating third-party access and IPP contracts, all of which are important considerations by prospective IPPs. However, there are indications that regulatory risks could disincentivise investments in SSA electricity sectors (Eberhard, 2017). Thus, we also introduced *reg* as a determinant of inefficiency in the model. We found a positive relationship between the presence of an electricity sector regulator and inefficiency. This indicates that the presence of a regulator could be a source of inefficiency in reform performance especially in an environment of poor regulation.

The significance of the coefficient of *unb* indicates that vertical unbundling of the electricity sector improves sector performance. This is a particularly interesting finding given that several SSA countries 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 the countries having introduced at least two other reform steps. Of these countries, Zimbabwe and Lesotho were the only unbundled electricity systems that featured in the top ten performers (details in the subsequent section in Figure 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 unbundling may be beneficial in large markets or when the country has access to a large market.

We also find that *pi*, introduced in the model as a control variable has a significant effect on reform performance. This indicates that private participation in the management and ownership of electricity assets has a positive impact on reform performance. The countries in the sample that had some form of private participation in their electricity sectors from 2000 to 2017 were Cabo Verde, Cameroon, Côte d'Ivoire, Equatorial Guinea, Gabon, Kenya, Liberia, Madagascar, Malawi, Mali, Nigeria, Rwanda, Tanzania, Togo and Uganda. Of these countries, only Nigeria had undertaken full privatisation, i.e., sold its generation and distribution assets. Uganda and Kenya on the other hand were trading electricity assets on their respective national security exchanges and in addition, Uganda have appointed Umeme as the private distribution concessionaire. Beside these four countries, sustained private participation contracts are concentrated in the Francophone African countries, i.e., Côte d'Ivoire, Gabon, Mali, and Cameroon. In several instances, the concessionaires are also majority shareholders in the utility. In the remaining countries, private participation was temporal, usually between two to three years or were failed privatisation attempts.

In several of these instances, cancellations were due to deteriorated sector outcomes with private participation. As a result, we also included *pi* in the model as a determinant of inefficiency. We found that *pi* was a source of inefficiency. This can be explained by the fact that private participation in the electricity sector of SSA countries are usually regulated with contracts. Unfortunately, the poor institutional capacity of several SSA countries often results in poorly designed contracts which are difficult to enforce. In several instances, such as the case of Liberia, contracts and corresponding performance targets were based on faulty data, making these targets almost unachievable by the private party. Thus, private sector participation often results in improved transparency and a corresponding upward revision of key sector performance indicators. Given that private participation is typically short-lived, this may result in a seeming deterioration of performance.

In the assessment of the impact of institutions, we found that political stability and absence of violence and terrorism, *ps,* has a significant impact on reform performance. This finding is as expected as electricity sector investments are usually sunk, making it particularly critical to consider a safe investment environment in investment decision-making. In addition, electricity sector assets have 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 the periods of prolonged conflicts in both countries.

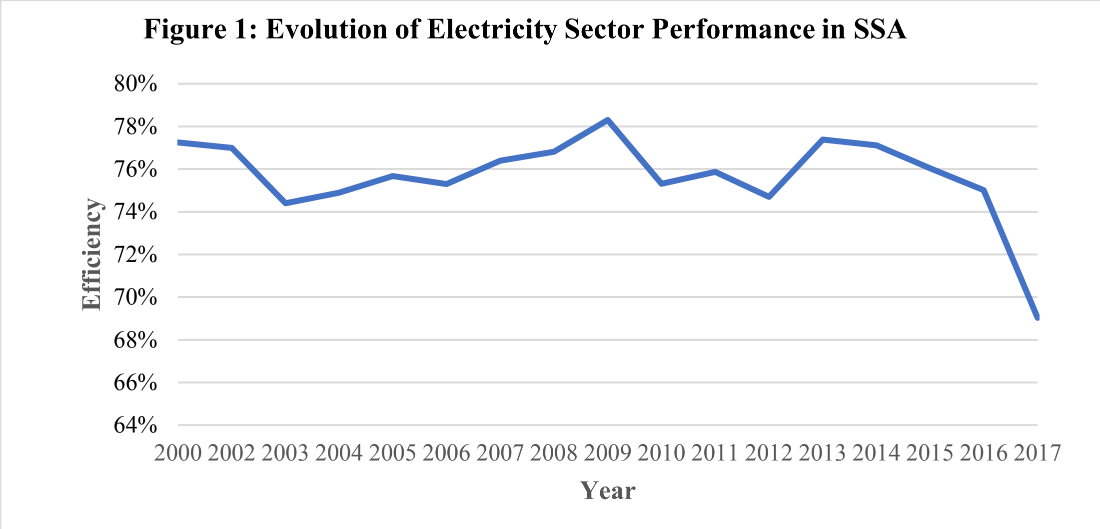
We also found that governance effectiveness index, *ge,* does not have a significant effect in reform performance. This indicates that perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies does not have an impact on 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 of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development has no impact on reform performance. In addition, we found that 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 as denoted by the control of corruption variable, *cc*, was not a source of inefficiency in reform performance.

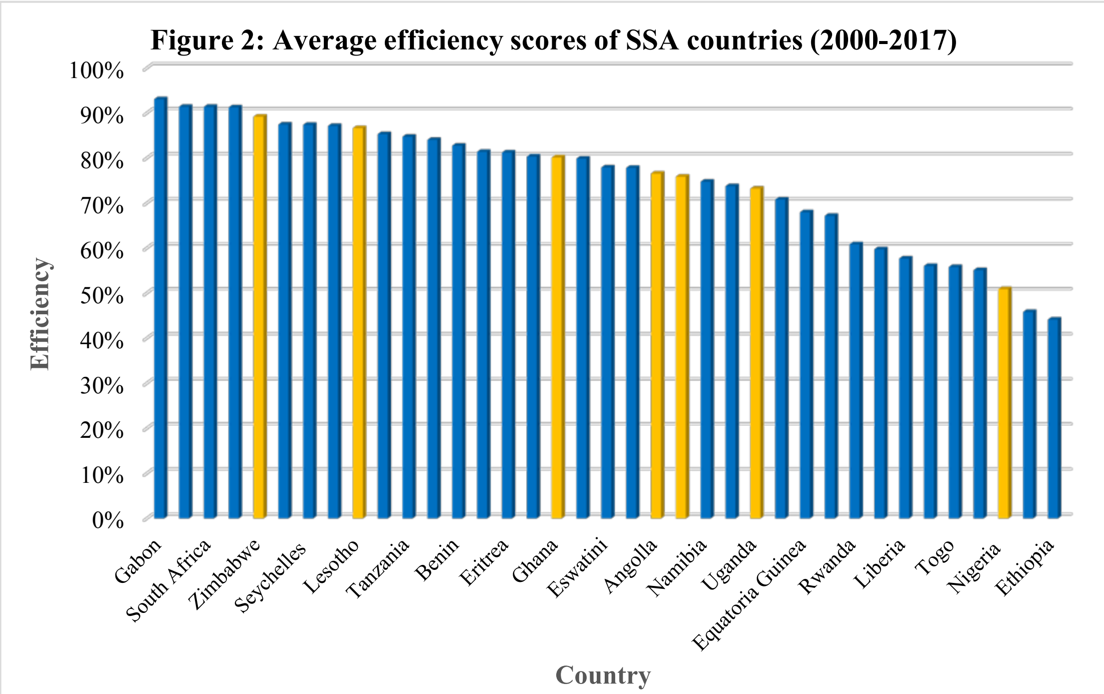
Our general sense from these results is that perceptions about non-violent institutional aspects does not have any impact on reform performance. This is in large part because commercial interests are usually protected in contracts, and thus perceptions of non-violent institutional features may not be a determinant of investment decisions especially as contracts are usually enforced by international judicial systems.

In order to determine the effect of the size of the electricity system on reform performance, we introduced *gc*, which is the level of installed generation capacity in MW as an inefficiency determinant. Our results indicate that the size of an electricity sector is a source of inefficiency in reform performance at 1% significance level. The negative relationship between the size of the electricity sector and inefficiency indicates that as the size of the electricity sector increase, inefficiency (u) decreases. We also found that the size of the installed hydroelectric capacity, *hydro*, has a significant effect on reform performance and as a source of inefficiency in the model.

Reform Performance

The reform performance trend in SSA has been irregular, with major dips in performance observed in 2003, 2010 to 2012 and 2017 as seen in Figure 1. From 2000 to 2003, there was a sharp decline. This decline can be explained as a as a learning curve effect as in the late 1990s and early 2000s most SSA countries initiated reforms. From 2003 to 2009, reform performance was improving, reaching its peak in 2009 with an average performance score of 78%. Between 2009 and 2012, reform performance fell to 2005/2006 levels at an efficiency score of 76%. This decline can be explained by the Great Recession in 2008/2009 which constrained access to capital globally. The performance recovery in 2012 to 2013 coincided with the shale revolution which led to a fall in global crude oil prices and increased economic growth in SSA countries which could have enhanced the performance of electricity sectors. We also estimated the efficiency scores for the countries in the sample with average reform scores of SSA countries presented in Figure 2 (See Appendix A1 for annual reform scores by country). The reform scores indicate the efficiency with which countries transformed reforms into the observed sector performance outcomes. We present a brief discussion on the four countries with the highest reform scores, i.e., Gabon, Côte d'Ivoire, South Africa, and Senegal.





Gabon

Gabon is a small upper-middle-income country with an estimated GDP per capita averaging $7,428 from 2000 to 2016. By the end of 2019, it had a population of about 2 million and was the fifth largest oil producer in Africa. The electricity sector of Gabon is vertically integrated, with the National Utility, the Société d'Electricité et d'Eaux du Gabon (SEEG) responsible for supplying electricity and water in the country. SEEG also purchases power from three IPPs; Grand Poubara, Alenakiri and Port-Gentil. An electricity law was enacted in 2005 but the sector was already under a concession with the France-based Compagnie Générale des Eaux (currently Veolia AMI, France) with ESB International (ESBI, Ireland) from 1997 to 2018.[23] Veolia owns 51% of the shares of SEEG, with the rest distributed among local investors. A key feature of the concession agreement with Veolia was that the development of generation capacity above 10MW was the state's responsibility. The Gabon Power Company (GPC) is a portfolio company of *Fonds Gabonais d'Investissements Strategiques* (FGIS) created in 2015 to develop generation capacity in collaboration with the private sector and sell to SEEG. The sector is regulated by *Agence de Régulation du Secteur de l'Eau Potable et de l'Energie Electrique* (ARSEE). The *Société de Patrimoine* was created in 2011 to own, operate and maintain critical energy infrastructure in the country including some thermal plants.

Gabon has one of the highest hydropower potentials in Africa, estimated at about 6000 MW, but it is not sufficiently exploited to meet rapid demand growth. The installed capacity of Gabon is 742MW of which 55% (412 MW) is thermal generation and the remaining 45% (330 MW) is hydropower based. Over the past 17 years, demand in GWh has increased by over 50%. Forecasted annual demand growth is between 6% and 13.5% requiring capacity additions of, 15-20MW annually. Technical and non-technical losses have increased from 12% in 2012 to 22.6% in 2018 owing in large part to insufficient investment in the transmission and distribution networks.

Côte d'Ivoire

Côte d'Ivoire has one of the longest experiences with reforms in SSA, having hosted the first IPP project in the region. The Electricity Law of 1985 liberalised the sector and the first IPP project, i.e., the 210MW Compagnie Ivorienne de Production d'Électricité (CIPREL) owned by the French Eranove group became operational in 1994. The success of CIPREL stimulated interests in the second IPP, i.e., the 330MW Azito gas-fired plant which came online in 2000 and was the largest IPP project in West Africa at the time. Now, IPPs supply more than a half of the electricity in Côte d'Ivoire. The electricity sector remains vertically integrated with the national utility – the Compagnie Ivoirienne d'Électricité (CIE) responsible for generation, transmission, and distribution. CIE is owned by Finagestion, a subsidiary of Emerging Capital Partners (54%), the State of Côte d'Ivoire (15%), private Ivorian investors (26%), and the CIE's employees FCP fund (5%).

The management of CIE has since 1990 been under a concession agreement with Eranove. The Autorité Nationale de Régulation du secteur de l'Electricité de Côte d'Ivoire (ANARE) is the electricity sector regulator with oversight over compliance with laws and regulations in the industry, tariff regulation, consumer protection and serves as the arbitrator of disputes amongst stakeholders. The 2014 Electricity Code gives ANARE greater independence and authority by designating it as an independent legal entity with financial autonomy. In addition, the Société

[23] Gabon's Ministry for Water and Energy terminated SEEG's water and electricity concession on allegations of deteriorated quality of service and complaints from consumers. Veolia won a 20-year concession to provide water and electricity in 1997, when it became majority owner of SEEG.

des Energies de Côte d'Ivoire (CI-ENERGIES) was created in December 2011 with the mandate to implement public sector electricity projects and undertake sector planning.[24]

A year prior to the commissioning of the Azito project, however, Côte d'Ivoire suffered a Coup d'état which delayed some investment projects. However, existing electricity sector infrastructures were not affected as most generation assets were concentrated in the southern part of the country while the war was actively in the north. As at the end of 2016, Côte d'Ivoire had an installed generation capacity of about 2,199 megawatts MW comprising natural gas-fired IPPs (1,320 MW at a 68% capacity factor) and hydropower (879 MW at a 27% capacity factor). Gross electricity generation in 2016 was more than 10,000 gigawatt hours (GWh), up from 8,607 GWh in 2015 (World Bank, 2017).

Due to increasing electricity access rates, industrial activity and higher energy exports, peak demand has grown at an average rate of 6.9% since 2011, reaching almost 1,300 MW in December 2016. Côte d'Ivoire is a net exporter of electricity to Benin, Burkina Faso, Ghana, and Togo. It is expected to increase its power exports to other countries in the WAPP after the commissioning of the Côte d'Ivoire-Liberia-Sierra Leone-Guinea (CLSG) transmission line.

Senegal

The electricity law of 1998 liberalised the Senegal electricity sector, and the first IPP, the Gti Dakar was commissioned in 2000. The electricity sector remains vertically integrated with the state-owned Sociéte Nationale de d'Electricité du Sénégal (SENELEC) responsible for all activities in the ESI. However, IPPs supply about 50% of the electricity to the grid. An independent sector regulator i.e., the Commission de Régulation du Secteur d'Electricité, (CRSE) was established in 1998 with the mandate to determine the sector revenue requirements, provide licenses for electricity sector activities and oversee IPP tender processes.

Currently, the electricity generation portfolio of Senegal is highly dependent on imported oil products, with thermal capacity accounting for 90% of electricity dispatched to the grid. The country recently discovered abundant gas resources which it has been utilising for power generation in recent years. Hydropower imports from the Organisation pour la Mise en Valeur du fleuve Sénégal (OMVS)[25] account for 10% of electricity dispatched to the grid.

The Government of Senegal is in the process of relaunching sector reforms along three policy pillars: (a) management and commercial performance of SENELEC; (b) the institutional framework and options for unbundling; and (c) grid extension and rural electrification. In parallel, SENELEC developed a Priority Action Plan (PAP) for 2016-18 which was an

[24] CI-ENERGIES was born as a result of the merger of Société de Gestion du Patrimoine du secteur de l'Electricité (SOGEPE) and the Société d'Opération Ivoirienne l'Electricité (SOPIE). Prior to the merger, SOGEPE oversaw the management of electricity supply and the design and construction of electricity projects on behalf of the State while SOPIE was mandated to make long term plans for the electricity sector. Overtime, it was observed that the objectives of the two institutions overlapped with each other's and thus had to be fused.

[25] The Organisation pour la mise en valeur du fleuve Sénégal (OMVS; in English Senegal River Basin Development Authority) is an organisation grouping Guinea, Mali, Mauritania and Senegal for the purpose of jointly managing the Senegal River and its drainage basin.

investment prospectus to finance the country's medium-term generation plan, reinforce the electricity network and improve service delivery.

South Africa

The South African electricity sector remains vertically integrated despite been the largest electricity system in SSA. The fully state-owned utility Eskom holds 91% of the country's gross generation capacity with the remaining generation capacity held by 137 municipal power companies (1.77%), Independent Power Producers (IPPs) that sell power to Eskom (7.21%). It has 30 operational power stations with a nominal generation capacity of 44,172MW, which is about 50% of the installed generation capacity in SSA. Eskom's generation portfolio comprises 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. Over the recent years, ESKOM has been refurbishing its networks in compliance with the national grid code and in preparation towards the integration of variable renewable energy.[26] Eskom was converted from a statutory body into a public company - Eskom Holdings Limited in July 2002, in terms of the Eskom Conversion Act, 13 of 2001. Over the years, South Africa has been facing generation capacity challenges resulting in periodic load shedding over the years.

The National Energy Regulator of South Africa (NERSA) is the regulatory authority established as a juristic person in terms of Section 3 of the National Energy Regulator Act, 2004 (Act No. 40 of 2004). NERSA's mandate is to regulate the electricity, pipeline gas and petroleum pipelines industries in terms of the Electricity Regulation Act, 2006 (Act No. 4 of 2006), Gas Act, 2001 (Act No. 48 of 2001) and Petroleum Pipelines Act, 2003 (Act No. 60 of 2003). South Africa is an integral part of the SAPP, trading electricity with Botswana, Lesotho, Mozambique, Namibia, Eswatini, Zambia and Zimbabwe. Total imports were 9,703 GWh in 2015/2016 and exports were about 13,465 GWh in the same period.

These countries share some similarities which are: they all remain vertically integrated have an electricity law and have an independent sector regulator. They also have abundant fossil fuel resources: coal in South Africa, gas in Senegal, oil and gas in Gabon, and gas in Côte d'Ivoire. In Gabon and Côte d'Ivoire, where there had been sustained private participation in the sector, the private sector were also shareholders in the utility. In both countries, the state also retained the responsibility of building additional generation capacity typically through designated state institutions which may partner with the private sector. A noteworthy observation is that, the two unbundled electricity systems (Lesotho and Zimbabwe) that were part of the top-ten most

[26] Eskom Transmission published the Generation Connection Capacity Assessment for the 2016 Transmission Network (GCCA-2016), which has been recently updated (July 2015) to provide a 2022 view (GCCA-2022). The assessments have indicated a constrained transmission network, particularly in the Northern Cape, Eastern Cape and Western Cape provinces, where most of the successful RE-IPP projects are located.

efficient reformers were both part of the SAPP. This suggests that access to a larger electricity market could be a panacea for effective unbundling.

6. CONCLUSION AND POLICY IMPLICATIONS

In this study, we assessed electricity sector reform performance for a set of 37 SSA countries from 2000-2017.We used a multi-input multi-output distance function to define a performance frontier comprising three efficiency 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, we 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 determinant to understand the effects of hydrology on reform performance. Lastly, we included the installed generation capacity (as a proxy for the size of the electricity sector) in the model as a determinant of inefficiency.

The results show that reforms have successfully increased electricity generation capacity per capita and improved the rate of increase of plant load factor in SSA. However, it was unsuccessful in reducing the rate of technical network losses. We also found that the presence of an electricity law, vertical unbundling of the electricity sector and the presence of an electricity sector regulator were significant inputs in reform performance as well as private participation introduced as a control variable. 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.

We found that perceptions about political stability and absence of terrorism and violence was a significant input in reform performance. However, perceptions about regulatory quality and governance effectiveness were not significant inputs. Also. perceptions of corruption were not a source of inefficiency in the model. The effects of hydrology on reform performance was negligible both as a control variable and as a determinant of inefficiency. Finally, we found a negative relationship between the size of an electricity sector and inefficiency indicating that larger electricity systems are more efficient in reforms than smaller ones.

We 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 of technical network losses. Hence, emphasis should be put on decoupling these losses from generation capacity and plant load factor. Smaller electricity systems should consider options that allow them to neutralise the scale limitations of their electricity systems such as partaking in regional electricity markets.

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Appendix A

Table A.1: Efficiency Scores of 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	80%	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%	0%
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%