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Institutions' and Electricity Sectors' Performance in Ghana

John Bosco Dramani[1*] and D. D. Tewari[2]

[1]School of Business, Garden City University College, Box KS 12775, Kumasi, Ghana
[2]Faculty of Commerce, Administration and Law, University of Zululand, KwaDlangezwa Campus: 1 Main Road, Vulindlela, KwaDlangezwa, 3886, South Africa

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ABSTRACT The paper examines institutions' and electricity sectors' performance in Ghana utilizing electricity sector performance indicators, yardstick competition and data envelopment analysis, revealing three findings: (i) institutions influence the reserve margin, and installed capacity positively, and possess the potential to affect the indices of global reliability measurement; (ii) various heterogeneous factors significantly affect yardstick competition; and (iii) the efficiency of the distribution companies vary over time. The present paper suggests that the Public Utility Regulatory Commission of Ghana use these factors together with others to set the rate-of-return for the various distribution utilities. Finally, it recommends that panel data procedure should be applied to analyze the efficiency of distribution utilities.

INTRODUCTION

Hitherto insignificant proposition, "institutions matter" (Voigt 2012) for the efficient performance of an economy, has gained immeasurable popularity in research areas in economics over the last two decades. This popularity was rekindled by the rise of New Institutional Economics (NIE) in the 1980s, championed by Nelson and Winter (1982), Williamson (1985), Simon (1986), North (1990) and others, who provided evidence of the important role that institutions play in promoting efficiency in economic activity. In the late 1990s, a popular view suggested that the stagnation of growth in most developing economies was attributable to the existence of poor-quality institutions (Chang 2010: 473). The World Bank, relying on this view, imposed numerous good governance related conditionality on these economies, demanding that they establish good governance institutions as a measure to obtain loans (Chang 2010: 473). Again, many historians suggest the potential determinants of modern growth have been technology and innovation which can be developed and made efficient through appropriate and good institutions (Javier et al. 2014). Thus, in an environment characterised by precise and adequate property rights and less transaction costs, private investors are capable of eradicating inefficiencies through competition resulting in growth (Dalibor 2014). Thus, the significance of institutions in an economy is that their existence will necessitate economic agents to act and behave in a proper way, more so than they would otherwise have done in their absence (Voigt 2012: 1). Even though the relevance of institutions have been duly acknowledged and applied in growth matters across countries, there is still no universally accepted definition of institutions and their classifications (Kunèiè 2013).

North (1990) defined institutions as regulations that collectively illustrate action situations, demarcate an action set, offer motivations, and determine results both for individual and joint decisions. The significance emanating from North's evaluation is that institutions shape the economic performance of organizations by influencing the intensity of transaction costs, and thus the viability and profitability of undertaking an economic activity. In an all-encompassing definition, Hudgson (2006: 18) identified institutions as systems of recognized and implanted, one or more social conventions that configure social relations. Greif (2006: 30) alluded to institutions as systems of conventions, values, customs and organizations that engender reliability in social behaviour. This definition has two significant components, namely: (1) institutions have observable components established by the regularity of behaviour, and (2) the nature of institutions is dichotomized into observable and non-observable units comprising formal (rules and beliefs) and implicit (norms and organizations). These definitions presuppose that the major objective of institutions is to pro-

*Address for correspondence:
E-mail: boscodramani@yahoo.co.uk,
tewarid@unizulu.ac.za

vide changes in organizational arrangement as a way of stimulating economic activities undertaken in an efficient manner. In addition, institutions entail changing the organizational environment, organizational structure and transforming the governance mechanism (Erdogdu 2012). Institutions can best facilitate productivity and improve the efficiency as well as impartiality of economic agents through changing the rules and regulations facing firms (Berggren et al. 2013). However, ascertaining the causal effect of institutions on growth and development as well as measuring their magnitude and understanding the know-how of transmitting institutional quality on economic progress are thought-provoking matters (Docquier 2014)

Ghana has, over the last two decades, suffered severe shortages in electricity generation and continues to demonstrate a conspicuous incapability of resolving the situation. Energy experts and analysts have indicated that Ghana's ability to resolve the situation mainly depends on effective electricity policy and an increase in the production of oil (Braimah and Amponsah 2012: 26). However, they have not considered institutions as effective tools for resolving the situation. Further, there is a dearth of literature that tackles the analysis of the performance of the electricity sector in Ghana. These gaps in the literature provide adequate grounds for writing this paper.

The present paper aims at achieving three objectives. First, it examines the influence of electricity institutions on the performance indicators of the sector to determine whether the indicators are consistent with universally accepted practice. This entails benchmarking key indicators to establish performance target standards in the generation segment. Second, it analyzes how regulators influence rate-of-return in the distribution segment through yardstick competition. In the distribution segment, managerial competency and efficient utilization of labour drive high productivity, unlike productivity in the generation segment that is basically determined by technology (Kumbhkar and Hjalmarsson 1998: 98). Yardstick competition is relevant because it provides for an optimal incentive arrangement and thus serves as an efficiency improvement regulatory tool. Third and finally, it evaluates the relative performance of electricity distribution firms using a deterministic data envelopment analysis (DEA), a non-parametric procedure in the framework of efficiency measurement for electricity distribution firms. The purpose is to determine the presence of distribution firms that operate significantly below the efficiency frontier.

The rest of the paper is structured as follows: section 2 presents an overview of Ghana's electricity sector and related institutions, section 3 deals with the methodology, section 4 presents the results discussion, and section 5 provides conclusions and section 6 looked at the recommendations.

An Overview of the Electricity Sector of Ghana and Related Institutions

Ghana is endowed with seven public electricity generating facilities comprising two hydroelectric and five thermal plants. The hydroelectric plants are situated at Akosombo and Kpong towns, respectively, and run by Volta River Authority (VRA), a public company. Akosombo and Kpong account for 60 percent of the total electricity generated with an installed capacity of 1180 MW (Adom et al. 2012: 531). Two of the thermal plants, Takoradi International Company (TICO) and Takoradi Power Company Limited (TAPCo), are situated at Aboadze, while the remaining three (Tema Thermal 1 Power Project, Tema Thermal 2 Power Project and the Mine Reserve Plant) are established at Tema. The five thermal plants account for the remaining 40 percent of the total electricity generated with an installed capacity of 763 MW (Adom et al. 2012: 531). Presently, plans are underway to increase the total installed capacity of VRA to about 1,930 MW (8,957 GWh), and the Bui dam project with an installed capacity of 400 MW (1000 GWh) is also under construction to satisfy the rising domestic demand for electricity (Braimah and Amponsah 2012: 26; Marchesini and Jenkins 1999: 1). The base load, that is, Akosombo and Kpong, are rainfall dependent, which has proved to be unsatisfactory since 1983 and has caused the country significant distress during droughts due to low water levels in the dams.

Economic and institutional reforms were introduced into the electricity sector in 1995 by the Power Sector Reform Committee, a body commissioned by the Government of Ghana to take responsibility for the process. The urgency to introduce reforms was underlined by the events in 1983 when the country experienced a series of power outages, blackouts and load shedding. The primary objectives of the reform processes were three-fold: (i) to pave the way for the introduction of a competitive market structure to attract independent power producers (IPPs); (ii) to strengthen public financing of the sector by a gradual process of phasing out both implicit and explicit subsidies; and finally (iii) a reduction in generation and supply costs (Clark et al. 2005).

Ghana's electricity institutions can be put into four categories, namely:

(i) *Policy-making Institutions:* The main policy-making institution is the Ministry of Energy (MoE) established in 1950. Its core duty is to provide electricity at minimum cost by developing, executing, examining and assessing policies suitable for the sector (MoE 2009). In addition, it is expected to implement policies to attract private capital for the generation of electricity (MoE 2009). The sector minister is the head and directly responsible to the president of Ghana.

(ii) *Regulatory Institutions:* They include the Energy Commission (EC), Public Utility Regulatory Commission (PURC), and Energy Foundation (EF). The EC was established in 1997 by an Act (Act 541) of Parliament to regulate and supply permits and licenses to producers and distributors of electricity. The PURC, another independent regulator, was established in 1997 by an Act of Parliament (Act 538) with the responsibility of regulating electricity tariffs and the quality of service delivery to consumers (MoE 2009). The EF is a non-profit public-private institution dedicated to promoting efficient utilization of electricity. It was established in 1997 by the Private Enterprise Foundation of Ghana, an institution that represents private sector electricity stakeholders to promote sustainable utilization of electricity in Ghana. The Foundation has the urgent responsible of promoting electricity demand management programmes in Ghana.

(iii) *Generation, Transmission and Distribution Institutions:* The Volta River Authority (VRA) and Sunon Asogli Power Plant [SAPP] handle the role of generation of electricity (Clark et al. 2005). The role of transmitting power is the responsibility of Ghana Grid Company Limited (GRIDCo), and the distribution to final consumers of all categories is carried out by both the Northern Electricity Department Company (NEDCo) and the Electricity Company of Ghana (ECG).

(iv) *Arbitration (Electricity Courts):* In 2011 the distribution companies in consultation with Ghana's Chief Justice instituted a court to prosecute cases involving electricity theft and other related cases. By the close of 2012 ECG had prosecuted about 24 different cases.

The institutions of the electricity sector of Ghana possess three principal characteristics. First, they are socially shared norms that require rules and regulations and thus the administration of sanctions. Second, they are formal or legal norms and actions that are carried out and imposed by the legal bodies in the country. Third, these institutions exhibit the characteristics of a convention because the enforcement of their decisions is supported by external bodies such as the World Bank. Thus electricity institutions refer to the economic, legal and regulatory humanly instituted framework that affects and maintains the continuity of the transformational process in the sector (Nepal and Jamasb 2013). The paper analyses institutions on electricity sector in the next subsection using the Institutional Decomposition Analysis (IDA) framework.

Institutional Decomposition Analysis (IDA) Framework

The IDA is defined as a framework that separates institutions and recognizes their institutional forms such as common doctrines and typologies that are relevant for understanding how different institutional parts are interrelated (Saleth and Dinar 2004: 31). It forms a key analytical procedure and theoretical framework for institutional research. A peculiar feature of IDA is its capability to provide the basis for a methodical evaluation of institutions.

IDA functions as a two-stage decomposition framework of institutions (Saleth and Dinar 2005). In the first stage, electricity institutions are broken down into electricity environment and electricity institutional structure. The electricity environment is influenced by factors such as historical, economic, political and physical conditions of the country while the institutional structure is determined by factors such as electricity-related law, policy and organizational elements. In the stage two, electricity institutional structure is divided into electricity law, electricity policy, governance and management and these institutional parts are divided further to underscore a few of the very relevant institutional portions. The institutional structure is shaped by political and economic endowments that are relevant for the effective functioning of the electricity sector since they are capable of promoting transparent, reliable, timely, and resilient transformation of the sector. This indicates a direct relationship between effective implementation of reforms measures in the sector and high quality institutions in a country (Erdogdu 2012).

The IDA framework is divided into four components and the factors influencing each of the four components can be controlled within the economy. As a result, the degree of variation of the factors that affects these components affects the performance of the electricity sector. The study briefly discusses the linkages of the four components as follows.

Electricity Law: Electricity law in Ghana provides legal support and a functional framework as well as administration and regulation of the supply of and demand for electricity. The law is composed of Acts, central government laws, constitutional provisions, court decisions, customary laws, criminal procedures and municipal and district bylaws (Edjekuhene et al. 2001). The law is meant to accomplish the following: consumer protection, government supply of electricity, accountability, rural electrification and private sector provision of electricity, arbitration and the prosecution of corrupt practices. The ultimate aim of electricity law is to ensure the establishment of economically productive, reliable and transparent, quality, safe and affordable electricity, as well an independent regulation and administration of the sector, resulting in a need to formulate policies (Leonard and Decker 2012). For instance specific laws and Acts permitted the introduction of a liberalization policy which brought into existence eight independent power producers (IPPs) to generate and supply electricity to bridge the supply shortfall.

Electricity Policy: Electricity policy refers to plans, legislation, incentives, guidelines and policy processes put in place by policy-making authorities such as the MoE to tackle concerns related to electricity production, distribution, and consumption. The MoE together with the EC of Ghana is required by law to prepare, review and update periodically indicative national plans to ensure that all reasonable demands for energy are met in a sustainable manner. In conformity with this mandate, the two institutions developed a Strategic National Energy Plan (SNEP) for the period 2006 to 2020 (Energy Commission 2006). The goal of SNEP is to contribute to the development of a sound electricity market that would provide sufficient, viable and efficient electricity services for Ghana's economic development (Energy Commission 2006).

Electricity Governance: Electricity governance involves a shared plan among civil society, policy makers, regulators and all key stakeholders in the electricity sector to uphold an open, transparent, accountable procedure that will promote socially and environmentally sustainable electricity into the future (Edjekuhene 2001; World Resource Institute and Prayas Energy Group 2010). The elements of good electricity governance comprise: (1) accountability; (2) capacity; (3) transparency; and (4) an institutionalized medium (Dixit 2007; Edjekumhene 2001). The governance of the electricity sector of Ghana has been entrusted to the two major regulatory entities: PURC and EC. Acts 548 and 451 established measures which allow policy that is formulated and implemented to affect governance activities (Edjekumhene 2001).

Electricity Management: Electricity management involves balancing demand and supply for electricity through various methods such as financial incentives to increase supply, regulation, removing entry barriers to suppliers, disconnection and reconnection, shortages and blackouts, load shedding, peak load management and education (Leonard and Decker 2012). Generally, the objective of electricity management is to attain and sustain optimal electricity supply and demand in a country, reduce the costs of electricity or waste without affecting supply and quality, and to reduce the negative environmental impact (Ghorude 2011). The management of electricity has been a challenge due to market failures. For instance, electricity consumption can change significantly in the short and medium term, while the tariff may not adjust immediately to keep demand and supply in equilibrium. Similarly, the compliance of electricity consumers to adjust to prices by modifying consumption is particularly low during the short run (Loughran and Kulick 2004).

METHODOLOGY

This section describes the methodologies that illustrate a comparison between key electricity performance indicators and some benchmarks for the sector, the role of regulatory institutions in implementing rate-of -return and the efficiency performance of the distribution companies.

Electricity Institutions and Performance Indicators

The impact of institutions on electricity sector performance is examined by analyzing the indicators of the sector, particularly during the period of institutional reforms from 1994 to the present. Prasad et al. (2009) accept that electricity sector indicators are performance variables that are obtained from parameters that provide information about the improvement or otherwise of the sector. The general objective of these indicators is to provide a comprehensible image of the industry's performance and then compare them to the regulatory benchmarks. The key performance indicators of the electricity sector are examined for generation, transmission and distribution.

Institutions influence the electricity sector indicators through a number of channels including: (i) they reduce both regulatory and non-regulatory uncertainties associated with investing in electricity generation, transmission and distribution by compensating and managing risks associated with the sector; (ii) they create incentives regulation to attract IPPs; (iii) they offer superior motivation for the management of construction and operating costs of new and existing generating capacity to ensure reliability and quality of supply of electricity, and promote innovation in supply technologies through competitive wholesale markets; and (iv) they influence the electricity sector through a reduction in transaction costs. North (1991) defined and characterized institutional transaction costs to comprise non-economic factors and added that institutions are capable of decreasing uncertainty by establishing a stable arrangement of human relations. The presence of transaction costs offers the investor several alternatives, from short-term to the selection of long-term contracts, and vertical integration (Onefri 2008). Finally, institutions influence (v) the institutionalization of independent regulatory bodies and deregulation which denote fundamental themes in World Bank donor support programs. In this way, institutions influence the electricity sector performance indicators with the objective of instilling efficiency. The present study categorizes the performance indicators into five, namely: (i) generation and reliability indicators; (ii) customer service indicators; (iii) metering, billing and revenue collection indicators; (iv) operational cost control indicators; and (v) financial performance and competiveness indicators. Due to limited space, the study selected and performed trend analysis using a few of these indicators, particularly generation and reliability indicators.

Yardstick Competition

Institutional influence on electricity sector performance indicators culminate in the emergence of third party access (TPA) that compels distribution utilities to permit fair admittance to companies that wish to transmit power to final consumers using the same transmission and distribution equipment (Filippini and Wild 2001: 478). Based on this limitation, distribution companies must unbundle their various functions: the distribution and supply functions. But since distribution companies still possess some elements of monopoly franchise in the delivery of electricity in their catchment areas, it is imperative to impose a rate-of-regulation on them (Filippini and Wild 2001: 478).

A failure to institute a rate-of-regulation by the regulatory commission will induce the companies to charge rates above those in competition situations. This situation poses the problem of formulating a rate that will safeguard the profitability of these companies without compromising welfare gains. However, the existence of information asymmetries prevents the regulator from knowing the true costs to the companies since inflated costs may be considered to reflect inefficiencies (Filippini and Wild 2001: 478; Shleifer 1985: 9). Regulators have attempted to resolve this issue through the application of a number of regulations such as rate-of-return and price-caps. However, these rates have been ineffective because they do not account for issues of inefficiency and are constrained in their reaction to wide-ranging shocks that affect costs to the companies.

Shleifer (1985) suggested yardstick competition in relations to pricing of electricity as a regulatory measure for distribution companies supplying a standardized commodity (electricity). This methodology illustrates that the regulated price to specific companies is dependent on the average costs of the related firms. This methodology is superior to the first two because it is capable of reducing asymmetric information between the regulatory body and firms on costs issues, and it incorporates wide-ranging shocks in the price-cap regulation rate and is very potent in the application of a multivariate average cost function to correct for the possibility of heterogeneity in output of the different companies (Filippini and Wild 2001: 479).

Specification of the Average Cost Function

The paper specifies an average cost function that excludes the expenses for purchasing electricity from the total costs. This approach is perfect for the purpose of benchmarking distribution network admittance rates. Burns and Weyman-Jones (1996) add that an ideal specification of the average cost function should comprise the following variables: (i) the system's maximum demand; (ii) the number of customers; (iii) the variety of the customers; (iv) customer density; (v) the size of the distribution area; (vi) the total electricity sold; (vii) system security; (viii) transformer capacity; and (ix) stretch of the distribution line. However, most of the variables are related and therefore can cause a serious problem of multicollinearity. This problem is addressed following Burns and Weyman-Jones suggestion of using relative rather than absolute variables. This study captures the maximum demand using load factor, and the output is denoted by gigawatts per hour (GWh) and the heterogeneity of customers is modelled by including low- and medium-voltage customers. Customer densities are used to capture the dispersion of consumers. The last three variables could not be included due to data unavailability. The costs of labour and capital were included in the model because they are important factors in the distribution segment.

Suppose the prices of the inputs and output are given, and at the levels of existing technology the firms alter the amount of input to minimize costs, then the average costs function can be expressed as:

$$AC = C/Y = AC(Y, PL, PK, LF, CD, DUMH, T) \quad \ldots\ldots\ldots(1)$$

where:

C denotes total cost of distribution in Ghana cedis *(GHc)*, *AC* denotes average costs per GWh, *Y* denotes output measure in *GWh*, *PL* and PKdenote prices of labour and capital, *LF* denotes load factor measured in percentage, *CD* denotes customer density, *DUMH* denotes dummy variable that divide companies into those that transport power using the high-voltage grid, and T denotes time that reflects the shift in technology which illustrates the variation in technical efficiency. All data were obtained from the annual reports of ECG, VAR, NEDCo and EC. Applying a log-linear method, the average costs function can be represented as:

$$\begin{aligned} InAC = {} & \phi_0 + \phi_1 InY^2 + \phi_2 InPL + \phi_3 InPk + \\ & \phi_4 InLF + \phi_5 InCD^2 + \phi_6 DUMH + \phi_7 T + u \end{aligned} \quad \ldots(2)$$

The study modelled the AC function in the form represented in equation (2) for two reasons: (i) the$Y^2$and CD^2 are meant to capture the nonlinear changes in the AC function; and (ii) the log-linear form is adopted so that the coefficients can be interpreted as elasticities. Expressing the coefficients in log-form makes it possible to apply the results in yardstick regulation.

Data Envelopment Analysis (DEA) of Panel Data

The seminal paper by Charnes et al. (CCR) (1978) popularized the application of the DEA framework to performance measurements. DEA is a linear programming and productivity theory-centred mathematical methodology and its principal objective is to compare elements of similar types by applying predetermined inputs (virtual inputs) and outputs (virtual outputs).The comparisons are made on the basis of decision-making efficiency (Charnes et al. 1978). Therefore, decision making units (DMUs) need to be identified as the constituents subject to comparison. The intuition is to assess efficiency levels of a given number of DMUs that produce given outputs by applying given inputs as the range for comparison, such that weights are generated and selected to illustrate which DMUs are most favourable (Resende 2002: 638).

The efficiency of a DMU is defined as the ratio of total output to total inputs (Romanathan 2003). By this definition, the efficiency level of all DMUs can be rated 100 percent when each one generates a relatively similar amount of output, which illustrates a perfect situation. However, the presence of inefficiency in some DMUs paved the way for the application of DEA as a vigorous efficiency measure and a goal projection instrument. The estimated DMUs rated 100 percent are considered the most efficient and become the benchmark for other DMUs. DEA assesses efficiency of DMUs from two perspectives: (1) either through output maximization subject to the given inputs or (2) inputs minimization subject to a given output. The two perspectives will yield the same outcome only in the situation of constant returns to scale.

Algebraically, assume a case of inputs (with the subscript), outputs (with subscript) and DMU (with subscript *J*). In addition permit $y_{rj} \succ 0$ to imply strictly positive values for inputs and output of the j^{th} DMU. Following the CRR model the paper illustrates the fractional programming problem as:

$$\max_{u,v} h_k = \sum_{r=1}^{s} u_r y_{rk} \Big/ \sum_{i=1}^{m} v_i x_{ik} \quad ..(3)$$

subject to:

$$\sum_{i=1}^{j} u_i\, y_{ij} \Big/ \sum_{i=1}^{m} u_i\, x_{ij} < 1 \text{ for } j = 1,2,\ldots k\ldots,n, \quad ..(4)$$

$$u_r \succ 0 \text{ (parameter } r = 1,\ldots,s) \; v_i \succ 0 \text{ (for } i = 1,\ldots,m) \quad \ldots\ldots(5)$$

Equation (3), which denotes the first constraint, shows that no DMU can function outside the efficiency frontier. Equation (4), depicting the second constraint, defines non-reactive weights. The solutions to these problems permit the production of comparative efficiency. Banker et al. (BCC) (1984) extended the CRR model by adding a third convexity constraint. By this extension the BCC model decomposed the total efficiency estimate in CCR into technical and scale efficiencies.

However, a DEA limited to only cross-sectional data analysis excludes the importance of time as it merely compares one DMU with others which generate results together. But this approach is misleading because the inclusion of dynamic situations may generate apparently extreme utilization of inputs meant to produce valuable outcomes in future. Panel data analysis therefore reigns over cross-sectional issues in two broad ways: (i) it ensures comparison are made between DMU and several others; and (ii) it provides an assessment of the development of efficiency of a DMU over a particular time span (Cullinane and Wang 2010).

To incorporate a dynamic time period into a DEA, assume denotes the period in time during which the observation was conducted and represents total time periods examined, thus inputs and output can be expressed as $(x_s^t) = (x_{s1}^t, x_{s2}^t, \ldots, x_{sm}^t) \in R_+^m$ and $(y_s^t)' = (y_{s1}^t, y_{s2}^t, \ldots, y_{sn}^t) \in R_+^n$. Tulkans and van den Eeckaut (1995) illustrated that unlike cross-sectional data which offer comparison between one DMU and several others within a practicable data set, panel data entails selecting only different subsets, referred to as reference observations subsets, instead of the complete data to estimate the efficiency of each DMU. Charnes et al. (1985) showed that every observation in a panel can be assessed in terms of efficiency in relation to variant types of frontiers described as follows:

(i) *Contemporaneous:* Entails making a reference observations subset at every time period such that the subsets are constructed at that time only.

(ii) *Intertemporal:* Entails making only one product set from the entire observation throughout its timespan.

(iii) *Sequential:* Entails making a reference production set at each point in time t, however, applying the sample conducted from points in time up until . Most studies exclude this procedure from the estimation since it possesses the potential of causing disproportion in the amount of observations with which the efficiency scores are calculated as goes towards .

(iv) *Window Analysis:* This is the time-related aspect of DEA. The intuition behind it is to treat each DMU as though it were a dissimilar one at each date indicated. Each DMU is then related to only the different options of subsets of the panel data. To apply window analysis in a DEA, denote w as the window width which defines the time period for all subsets of the observations. Thus a single window observations subset can be written as:

$$\left\{(x_s^h, y_s^h) \,\middle|\, s = 1,2,\ldots,s;\, h = t, t+1, \ldots, t+w;\, t \le T - w\right\}$$

Subsequent windows, defined for gene- $t = 1, 2, ..., T - w$, rate a series reference production set.

The independent regulatory institutions introduced varied reforms into the electricity sector. First was the change from the rate-of-return regulation (ROR) in pricing to the price-cap and automatic tariff adjustment formula (ATAF) regulations. Second, they introduced competition into the generation and supply as well as the distribution end points. Currently, the generation end-point has become competitive with the establishment of eight IPPs to VRA. However, since 1989 the distribution end-point has remained a duopoly market structure under the ECG and NEDCo. This situation makes it imperative to formulate an efficiency-stimulating regulatory mechanism to ensure delivery of quality services. The DEA framework is thus applied as a regulatory instrument to promote efficiency-stimulating activity in the distribution segment through a comparative efficiency assessment. The sample is panel in nature and covers the period 1990 to 2010 with respect to the two distribution companies, and the variables used include the following: CONS: number of customers, RCON: residential consumption (GWh), ICON: industrial consumption (GWh), NEMP: number of employees, and NETE: network extension (number of new connection in a year).

RESULTS AND DISCUSSION

This section provides a discussion of the results on the performance indicators and benchmarks, yardstick competition and DEA.

Results of Performance Indicators and Benchmarks

The results in Figure 1 depict the trend of reserve margin (RM), a generation and reliability indicator spanning 2000 to 2011. The reserve margin, defined as the anticipated maximum existing supply and demand predicted peak demand, has been weak as it falls short of the industry standard minimum level of 15 percent. The reserve margins for 2003 and 2004 do not include the Volta Aluminium Company's (VALCO) demand since it was shut down due to power shortages. With the VALCO demand included, the reserve margins would have been -7.1 percent and -6.2 percent, respectively (GRIDCo 2010). The current 10.1 percent indicates that the electricity system has excess capacity of 10.1 percent of predicted peak demand translating into 140 megawatts (MW). However, each generating unit at Akosombo and Aboadz towns exceed 100 MW in capacity; thus, the failure of any of these units will completely wipe out the reserve margin and dictate instant load shedding. The resultant effect is a weak transfer reliability of distribution to major areas. The institutional role over the decade has been the granting of permits to eight IPPs to increase electricity generation so as to raise the reserve margin to the required standard.

In Figure 2, the installed capacity (ICAP) remained constant below 1500 MW from 2000 to 2007, and rose thereafter to a little over 2000 MW. Institutions have influenced ICAP positively through: (i) installation of six million electricity-saving bulbs in 2007, and (ii) granting a

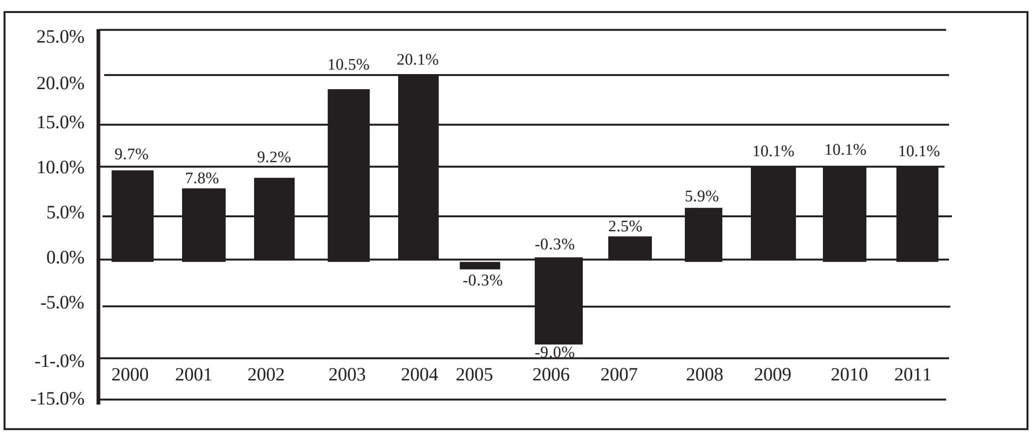

Fig. 1. Reserve margin, Data source (GRIDCo 2012)

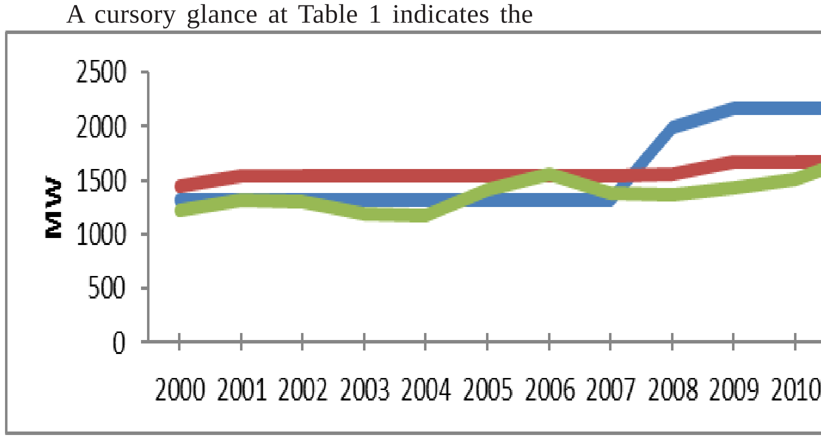

Fig. 2. ICP, DCAP and PD Data source

permit which allowed Sunon Asogli Power Plant (SAPP), an IPP, to start electricity generation in 2010. Again, in Figure 2, dependable capacity (DCAP) is fairly constant and tends to be affected by being dependent on hydroelectric plants and oil supply risks. To alleviate these risks, institutions involved in electricity have proposed the introduction of solar energy in the country and in 2015 a solar power plant of 155MW capacity will be constructed in Ghana. Furthermore, peak demand (PD) is also high and fairly constant and institutions have proposed the implementation of smart metering technology to ease it (EGC 2012).

In addition, other global reliability indices that institutions have influenced over the years include: (i) system average interruption duration index (SAIDI), which quantifies the mean number of hours of interruption encountered by customers; (ii) system average interruption frequency index (SAIFI), which measures the frequency of interruption encountered by customers due to outages transmission issues, and (iii) customer average interruption frequency index (CAIFI) computed to indicate the trends in customers interruption in a given time period and the three indices are shown in Table 1.

A cursory glance at Table 1 indicates the

Table 1: Global reliability indices 2010

Benchmark item	*Index*	*Unit*	*Metro and*	*Urban municipal*	*Rural*
Regulatory Requirement	SAIDI	Hours	48	72	144
	SAIFI	Times	6	6	6
	CAIDI	Hours	8	12	24
Current Performance	SAIDI	Hours	248	190	206
	SAIFI	Times	69	88	124
	CAIDI	Hours	16	5	5
Projected performance	SAIDI	Hours	172	133	144
	SAIFI	Times	48	62	87
	CAIDI	Hours	11	4	4

Source: ECG (2012)

exchange rate losses so as to reduce delays in power purchase agreements.

Results of Yardstick Competition

Previous studies indicated three major econometric methodologies in the estimation of yardstick competition, namely: (1) the ordinary least squares (OLS), (2) least squares dummy variable (LSDV) model, and (3) the error components models (EC). However, the presence of constant values of some variables renders the LSDV methodology inappropriate. As a result equation (2) was estimated using the OLS and EC models. The descriptive statistics are shown in Table 2.

The results of the OLS and EC of the average-cost function are presented in Table 3. In the estimation of equation (2) the dummy variable denoting firms operating on low- and medium-voltage and time were dropped due to the severity of multilcollinearity. The estimated model behaved appropriately as most of the coefficients were statistically significant.

All variables indicated the expected a priori signs. The *Y* variable is negative, indicating a reduction in output generates a decrease in the AC. The Y^2 is statistically significant at the 5 percent level even though the magnitude of the coefficient is small. The customer densities in both models are negative and robust. The coefficients denote evaluated elasticity of costs to variations in customer density. The negative sign supports that costs decreases as customer density increases. There is thus a reduction in costs due to the proximity of customers with each other. The price of labour is also significant and robust. The coefficients indicate that a 1 percent increase in labour price induces about 0.3112 and 0.2221 percent increase in the costs of distribution. The price of labour is significant compared to capital due to the following reasons: (i) 60 percent of the over 2 million total customer population of ECG use credit meters which demand large number of employees to conduct the monthly reading and billing; (ii) the demand for labour to respond to the increasing growth of vegetation (bamboo, raffia trees, etc.) that interfere with the 11kv and 33kv networks; and (iii) increasing public education about electricity usage, particularly in the rural communities, demand the engagement of more labour.

The price of capital is insignificant for both models because it forms a smaller proportion of the costs of distribution. For instance, both distribution networks are currently facing the following key technical challenges due to low investment in capital equipment: (i) high technical losses of about 10.62 percent; (ii) aged equipment and poor power system reliability; and (iii)

Table 2: Descriptive statistics

Variable	*Description*	*1. Quartile*	*Medium*	*3. Quartile*
Average cost	Average cost	8.25	16.74	43.02
Output	Output	238	861	3080.34
Price of labour	Price of labour	62.14	430.59	5103
Price of capital	Price of capital	50	380.50	5600.30
Load factor	Load factor	0.10	0.12	0.13
Customer density	Customer density	0.75	1.92	9.51

Source: Authors' computation

Table 3: Estimated AC function

Variable	*EC (FE)*		*OLS*	
	Coefficient	*t-ratio*	*Coefficient*	*t-ratio*
Constant	18.9731*	1.65	19.2653*	1.74
Output (Y)	-2.4996*	-1.65	-2.7103*	-1.71
Y^2	0.00001**	2.44	9.e+08*	1.80
Customer Density (CD)	-0.0022***	-90.53	2.9811**	2.20
CD^2	3.1508**	2.54	-0.0022***	-14.86
Price of Labour	0.3112***	22.61	0.2221***	16.06
Price of Capital	0.0013	0.01	0.0648	0.34
Load Factor	-0.2014**	-2.43	-0.3589***	-4.35
Adjuster R^2	0.46		0.47	

Note: *, ** and *** denote significant level at 10%, 5% and 1% respectively.

inadequate spare parts for effective operation and maintenance.

The load factor for both models is significant and robust. The negative relationship indicates a 1 percent reduction in load factor results in a 0.2014 percent reduction in AC. In effect, minor variations of electricity demand in a given period of time will reduce average costs. Distribution companies will need to improve the load factor by distinguishing the time-of-use rate as a measure to reduce average costs. This implies electrical loads should be designed so that customers with a high load factor are charged less per kilowatts per hour (kWh) since the overall distribution AC reduces. This result corroborates the finding of the Filippini and Wild (2001) paper.

Application of Results to Yardstick Regulation

Equation (2) incorporates three variables that illustrate the heterogeneity of the distribution companies. These variables, which include customer density, output per customer and load factor, significantly affect variations in the average costs. The paper estimates them separately and reports the results in Table 4. The coefficients represent the average cost elasticities of the heterogeneous variables and are relevant for the computation of a specific price-cap for the utilities by the regulator (PURC). Price-caps reflect the heterogeneity of the service area, customer and demand features which cannot be altered by the utilities.

The application of the yardstick method to regulate price-caps of individual utilities is only possible when the regulator is capable of observing and evaluating each of the heterogeneous factors. The customer density heterogeneous variables significantly influence the regulator in setting the rate-of-regulation for utilities. It suggests that distribution companies with high customer density be regulated to charge a lower price per kWh than those with low customer density. Kumbhakar and Hjalmarsson (1998) suggested that utilities with high customer density that keep constantly high rates should be allowed to merge with others or be made to lose their concession. The main limitation of yardstick regulation is the fragile inducement it permits for cost minimization in utilities situated in high customer density population (Kumbhakar and Hjalmarsson 1998). This implies there are no benchmarks to provide a challenge to these firms. However, Kittelsen (1995) proposed a procedure to yardstick regulation that is not limited by this weakness.

Empirical Results and Analysis of DEA

The descriptive statistics of the variables used in the estimation are indicated in Table 5.

Table 4: Estimated average-costs elasticities of service area characteristics

Heterogeneity factors	*EF*		*OLS*	
	Coefficient	*t-statistic*	*Coefficient*	*t-statistic*
Customer density	-0.62*	(-1.99)	-0.25**	(-2.38)
Average consumption per customer	-2.93*	(-1.70)	-1.07*	(-2.77)
Load factor	-1.87**	(-3.19)	-1.42**	(-1.6)
Constant	-17.72*	(-1.68)	-6.68***	(-1.78)

Note: *, ** and *** denote significant levels at 10%, 5% and 1%.

Table 5: Descriptive statistics of DEA model

Variable	*Minimum*	*Maximum*	*Mean*	*Standard deviation*
EDIST	254.63	2942.16	1598.39	1900.37
RCON	208.92	1136.38	672.65	655.81
IRCON	0.0254	2685.09	820.9516	1160.96
NEMP	680.57	3438.52	2059.54	1950.16
NETE	55.90	436	245.95	268.76
CONS	25000	2118042	517959.3	574467

Source: Authors' computation

The results show significant non-uniformity in the observations, with some utilities, even though small in size, undertaking huge network extension and distribution. In this circumstance the application of DEA is appropriate since it permits the dichotomization of scale effects.

The results of the efficiency estimates of ECG and NEDCo using window and intertemporal analysis are depicted in Tables 6 and 7. According to Cullinane and Wang (2010) extreme consideration should be given in the definition of window width when conducting window analysis. Generally, the size of the window should concurrently illustrate and depend on data availability and the number of variables vital for the analysis. Preferably, the window width should relate to the typical cycle time between technological improvements to make the estimated efficiency values differentiate the actual production level of a DMU from the best level of intertemporal production. However, several studies have shown that in practice it is difficult to detect technological time cycle in firms. Based on this, the study arbitrarily chose an extreme width of 11 and 21 time period for the analysis.

The DEA window and intertemporal procedures avail themselves to "trends" study of efficiency over the 21 sample period by applying a "row view''. This is important since the efficiency of the distribution utilities varies and differs over time. For instance, Table 6 reveals that the efficiency level of distribution of ECG varies from 100 percent in 1991 to 95.75 and 96.09 percent during 2008, through to 2009 and to 100 percent in 2010. Again NEDCo efficiency varies from 78.23 percent to 89.24 and 91.36 percent during 2008, through to 2009 and 2010. Window analysis is also robust in the examination of the stability of efficiency by applying a "column view". The strategy is important as it offers the opportunity to discern variations of the efficiency of DMU within distinct windows. The examination of "trend and stability" in Table 6 reveals concurrently both the total performance of a utility company in a given time period and its performance compared to others in the sample.

The results in Tables 6 and 7 revealed the presence of some degree of inefficiency in the utilities. The general averages of the utilities regarding window and intertemporal analyses are 98.53 and 90.62 percent. The window implies that, in general, ECG and NEDCo theoretically could have decreased their inputs by about 1.47 percent and still maintains the same output levels, if they had applied the most favourable practices.

The intertemporal analysis also implies that on the average, ECG and NEDCo could have decreased their inputs by 9.38 percent if they had adhered to the best practices and avail themselves of modern technologies. The degree of volatility of efficiency of the utilities is captured by the mean efficiency and their standard deviation (SD) scores in Tables 5 and 6. These results revealed that there are remarkable variations of the SD from the means. This indicates high levels of volatility in the efficiency scores.

The results in Figure 3 indicate the trend of year-to-year average efficiency of both distribution companies applying window and intertemporal analyses. Generally, it depicts a sharp rise in average efficiency for window, which falls and becomes relatively constant. This implies technological development among the utilities rose in 1994, basically attributable to the commencement of institutional reforms. The average efficiency for intertemporal compared with window is virtually flat. This illustrates that technological and managerial developments in the sector have paved the way for improved efficiency. Furthermore, Figure 3 shows that technological improvement may not automatically translate into efficiency. This is evidenced by the fall in efficiency from 1994 to 1995 for window, and 2001 to 2002 for intertemporal. Culli-

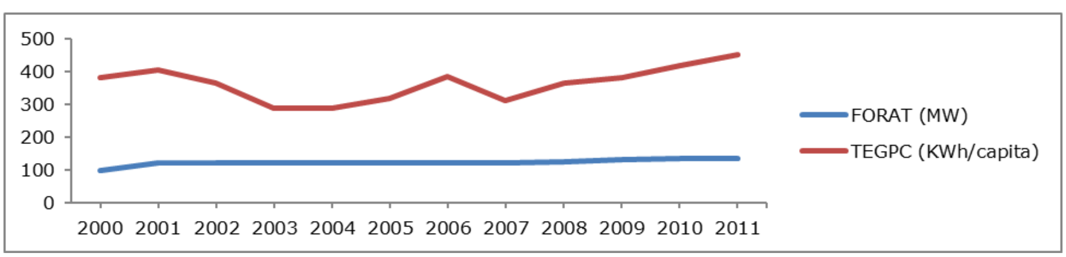

Fig. 3. FORAT and TEGPC Data
Source: GRIDCo (2012); Energy Commission (2012)

Table 6: Window analysis of electricity distribution utility efficiency (100=efficient)

Utility	Efficiency scores																					Summary measures	
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Mean	SD
ECG	100	100	100	89.26	88.44	82.93	100	100	88.88	100	100											95.41	6.742045
		100	100	89.11	87.99	82.19	100	100	88.81	100	100	100										95.28182	6.785063
			100	98.31	91.61	87.08	100	100	88.5	94.72	99.31	90.36	100									95.44455	5.152037
				100	97.04	91.58	100	100	89.28	95.51	91.38	91.16	100	100								95.99545	4.367909
					100	94.21	100	100	89.33	95.77	92.48	91.77	100	100	96.64							96.38182	3.960242
						100	100	100	89.34	95.77	92.95	94.31	100	100	98.18	99.8						97.30455	3.701882
							100	100	89.34	95.77	94.28	97.99	100	100	99.32	100	100					100	0
								100	89.77	99.8	98.96	99.93	100	100	99.31	100	100	97.29				98.64182	3.054642
									100	100	100	100	100	100	99.14	99.79	100	96.94	100			99.62455	0.927182
										100	100	100	100	100	95.94	97.31	100	96.41	100	100		99.06	1.639762
											100	100	100	100	94.73	95.85	98.4	93.43	95.75	96.09	100	97.65909	2.525718
NED Co	78.23	72.19	100	90.44	89.17	90.46	98.1	100	84.21	84.67	84.48											88.35909	8.861253
		72.36	100	90.85	89.42	90.66	98.19	100	84.24	84.73	84.55	87.25										89.29545	8.200582
			100	95.94	92.22	92.81	99.1	100	84.26	84.76	84.59	87.32	94.55									92.32273	6.238033
				100	96.13	95.12	100	100	84.36	84.95	84.81	87.6	77.2	81.49								90.15090	8.305475
					100	97.13	100	100	84.45	100	100	87.83	79.45	100	87.11							94.17909	7.835114
						100	100	84.58	85.36	85.28	88.22	88.76	83.76	86.92	92.66	100						90.50364	6.562011
							100	100	84.58	85.36	85.28	88.22	85.17	86.92	93.86	100	93.75					91.19455	6.499491
								100	84.58	85.36	85.28	88.22	85.17	86.92	93.86	100	93.75	92.49				90.51182	5.843362
									100	99.12	97.98	100	92.33	92.75	97.36	100	93.75	92.75	98.37			96.76455	3.199185
										100	98.41	100	94.54	94.54	98.38	100	92.92	91.25	95.96	97.19		96.65364	3.041425
											100	100	100	97.91	97.2	99.86	100	91.52	89.24	91.36	91.16	96.20455	4.407388

Note: All efficient estimates have expressed over 100 to show the concept of attaining 100% efficiency.

Table 7: Intertemporal analysis of electricity distribution utility efficiency (100%=efficient)

Utility	*Efficiency scores*											*Summary measures*	
ECG	*1990*	*1991*	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*Mean*	*SD*
	100	100	100	90.2	94.68	93.28	100	82.53	80.13	80.82	83.34		
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010			
	100	100	91.31	92.43	90.9	96.9	90.45	94	95.42	100		93.16143	6.731565
NEDCo	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000		
	100	71.84	100	78.28	81.68	86.53	100	100	90.45	93.73	96.45		
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010			
	100	73.66	78.4	79.57	85	79.83	91.37	82.06	87.86	93.16		88.08905	9.342628

Note: All efficient estimates have expressed over 100 to show the concept of attaining 100% efficiency.

nane and Wang (2010) attributed this situation to the acclimatization periods for the adoption and usage of a new technology.

A chi-squared test of average efficiency for window and intertemporal analyses (χ^2=357) implies that computed means of the efficiency estimates using the two methods are not significantly different at the 5 percent level. Therefore, the application of each one will generate almost the same efficiency scores. This is confirmed by the Spearman correlation coefficient of 0.34 which is also insignificant at the 5 percent level, implying that the rank of relative efficiency measures of ECG and NEDCo computed by the two methods are similar.

CONCLUSION

The paper examines institutions and electricity sector performance in Ghana spanning 1990 to 2010. It utilizes three procedures: (i) institutional effects on the performance indicators of the electricity sector; (ii) the role of regulatory institutions on rate-of-return applying yardstick competition; and (iii) measuring the efficiency levels of the distribution segment using DEA.

Procedure (i) revealed that institutions influence the RM, ICAP, and PD positively and possess the potential of reversing the negative trends of global reliability indices such as SAIDI, SAIFI and CAIDI. Thus, institutions should be considered an important tool in addressing Ghana's electricity problems. In procedure (ii) the study estimated an average-costs function for Ghana's two distribution utilities as a basis for yardstick competition for regulation of network admittance prices. The results showed that various heterogeneous factors, such as customer density and load factor, significantly affect average costs. Procedure (iii) applied a dynamic analysis involving panel data. Two methodologies of DEA, namely, window and intertemporal analyses, were estimated. The findings showed that the efficiency of the distribution companies can vary over time.

RECOMMENDATIONS

The present paper suggests that the PURC use customer density and load factor together with others to set the rate-of-return for the various distribution utilities. The paper also recommends that panel procedure and different me odologies used in the analysis of panel data should be employed in order to obtain a pragmatic understanding of the true efficiency of the distribution utilities. Finally, the distribution segment performance needs to be examined continuously over time.

LIMITATIONS

The major limitation of the paper is the lack of data on system security, transformer capacity and stretch of the distribution line which could have better improve the findings.

DIRECTION FOR FUTURE STUDIES

Future research on a similar topic should not only be focused on the distribution segment but should be extended to cover the generation and transmission segments as well.

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