# ECONOMETRIC ASSESSMENT OF THE IMPACT OF POWER SECTOR REFORMS IN AFRICA: A STUDY OF THE GENERATION, TRANSMISSION AND DISTRIBUTION SECTORS.

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## Declaration

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## Abstract

The objective of the thesis is to use econometric analysis to assess the impact of power sector reforms in Africa during the period 1988-2005, using panel data analysis. The study uses fixed effects model, where all the reform variables are assumed to be strictly exogenous, but goes a step further, to endogenise the variables using 1-step Generalized Method of Moments (GMM) estimation. To ensure the robustness of the results, the study makes use of both static and dynamic models and other econometric methods to reduce as far as practicable, the likelihood of spurious correlation.

The main conclusion from the generation sector study is that, the establishment of a regulatory agency is generally associated with favourable generation outcomes. These are likely to be achieved after a minimum period of 2 years for installed plant capacity, 3 years for plant energy output, and 7 years for plant utilization. Passage of energy sector law seems likely to enhance both installed generation capacity and actual plant energy output.

On the impact of private sector participation (PSP) in the generation sector, management and lease contracts, as well as greenfield projects seem likely to enhance installed capacity and actual plant output. On plant utilization, the favourable outcome is associated with concessions and greenfield projects.

For the network sector, the result seems to indicate that the co-existence of energy sector law and regulatory agency can reduce transmission network loss levels. The result on the distribution system however show that though energy sector law and regulation are necessary, they are not likely to be sufficient to reduce the system loss level. Effective loss reduction in the distribution sector is likely to be achieved if management and lease contract is present as a PSP option.

The long lags associated with the existence of regulation, underline the notion that institutional changes alone are unlikely to be sufficient, if the workforce is not competent and well trained. This implies that regulatory agencies in Africa are still fragile, and it will take quite sometime to build the capacity of key professional staff to operate whatever institutional and regulatory frameworks are chosen.

## Abbreviations and Acronyms

| | |
|---|---|
| **AFREPREN** | African Energy Policy Research Network |
| **AFUR** | African Forum of Utility Regulators |
| **CAPP** | Central African Power Pool |
| **COMPFMKT** | Competition ‘for’ the Market |
| **EAPP** | East African Power Pool |
| **ECOWAS** | Economic Community of West African States |
| **EFW** | Economic Freedom of the World |
| **EIA** | Energy Information Administration |
| **EEPCO** | Ethiopian Electric Power Corporation |
| **ESI** | Electricity Supply Industry |
| **ESLAW** | Energy Sector Law |
| **ESMAP** | Energy Sector Management Assistance Programme |
| **FRI** | Formal Regulatory Index |
| **GDP** | Gross Domestic Product |
| **GHGs** | Greenhouse Gases |
| **GMM** | Generalised Method of Moments |
| **GWh** | Giga watt-hour |
| **IEA** | International Energy Association |
| **IMF** | International Monetary Fund |
| **IPP** | Independent Power Producer |
| **IP3** | Institute for Public-Private Partnerships |
| **IRI** | Informal Regulatory Index |
| **ISO** | Independent System Operator |
| **kW** | Kilowatt |
| **kWh** | Kilowatt hour |
| **kV** | Kilovolt |
| **LRMC** | Long Run Marginal Cost |
| **LSDV** | Least Square Dummy Variable |
| **MW** | Megawatt |
| **MWh** | Megawatt-hour |
| **OECD** | Organisation for Economic Co-operation and Development |
| **PCA** | Principal Component Analysis |
| **POLCON** | Political Constraint Index |
| **PPA** | Power Purchase Agreement |
| **PPI** | Public-Private Investment |
| **PPIAF** | Public-Private Infrastructure Advisory Facility |

| | |
|---|---|
| **PSP** | Private Sector Participation |
| **SAPP** | Southern African Power Pool |
| **SCADA** | Supervising, Control and Data Acquisition |
| **SENELEC** | Société Nationale d'Electricitè, Senegal |
| **SOE** | State Owned Enterprise |
| **SRMC** | Short Run Marginal Cost |
| **TANESCO** | Tanzania Electric Supply Company Limited |
| **WAGP** | West African Gas Pipeline |
| **WAPP** | West African Power Pool |
| **WEC** | World Energy Council |
| **ZESCO** | Zambia Electricity Supply Company |

# CHAPTER 1 INTRODUCTION

## 1.1 Problem Statement

Africa's energy resource base is rich and this is manifested by the hydro-power potential of Africa estimated at 10% of total world hydro power, with most of it still untapped (ESMAP 2006). Out of this, 65% of the exploitable hydro capacity is in East and South Africa, 34% in West Africa and about 1% in North Africa (Redwood-Sawyerr 2002)[1]. Currently, 7%, 6%, and 7.2% of the world's proven reserves of oil, coal and natural gas respectively, are in Africa (British Petroleum 2004), while 7 out of 8 recent oil finds or a growing number of new gas fields are in Africa (Davidson 2002). Africa's coal reserves amount to 63 Billion tons, with over 90% in southern part of Africa (Karekezi and Mackenzie 1993).

Despite the fact that the continent is richly endowed with fossil fuels (i.e. coal, oil and gas) averaging about 7% of the world resources, exploiting them to provide good quality of life has remained an uphill task, and the continent still depends on non-commercial fuels to satisfy its energy needs (ESMAP 2006)[2]. Though Africa is estimated to produce about 7% of world commercial energy, it only consumes 3% (Davidson and Sokona 2002). In the majority of sub-Saharan African countries, wood-fuel constitutes about 80%-90% of energy consumption of the residential energy needs of low-income households (International Energy Agency, IEA, 2002). According to IEA (2002), since there is a correlation between a country's poverty level[3] and electricity access[4], the extremely low electrification rate[5] is an indicator of

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**1** Africa is estimated to possess a technically exploitable hydro potential of 1,888 TWh/year, with about 415 in the Democratic Republic of Congo. See further details in US Department of Energy, DOE, (2000): See also ESMAP (2006), "Energy and the Millennium Development Goals in Africa", A paper commissioned by the Forum for Energy Ministers in Africa, for the UN World Summit, held in September, 2005.

2 Smith (1998) notes that the inefficient use of firewood and charcoal, especially in poorly ventilated areas, has lead to adverse emissions which has been linked to diseases and other chronic respiratory diseases such as tuberculosis, bronchitis and lung cancer. Detailed discussions are in Smith, R. (1998), "The National Burden of Diseases from Indoor Air Pollution in India", Mumbai, Indra Gandhi Institute of Development Research.

**3** According to the World Bank (2001), being below the poverty line is defined as having income of less than US$2 per day. People with income below US$1 per day are classified as 'very poor'.

**4** Access to electricity is defined as the number of people with electricity in their homes, either grid or off-grid.

**5** In Africa, the average electrification level is about 34%, compared to the developing country average of 64% and the world average of 73%.

Africa's stagnant economic development. Modern energy has the biggest effect on poverty by boosting poor people's productivity and their income, and it is imperative that the energy sector works with other sectors to ensure that the poor benefit from greater accessibility (World Bank 2000).

The abundant energy resources in Africa have been under-utilized [6], mainly because of weak institutional, structural, legal and regulatory frameworks, as well as lack of well-focused energy policy framework (Karekezi and Mutiso 1998; Economic Commission for Africa 2003). The inability of governments to mobilize the needed financial resource, and inappropriate energy pricing policies has also been a contribution factor (Bhagavan 1999; Economic Commission for Africa 2003). For instance, electricity supply functions were the sole responsibility of state-owned vertically and sometimes horizontally integrated entities, established by Acts of Parliament (Karekezi and Mutiso 1998; Mkhwanazi 2003). A distinctive feature of the energy sector in sub-Saharan Africa in the wake of independence was the virtual absence of any coherent institutional framework for formulating energy policy, monitoring and implementing, as well as updating those policies (Davidson and Karekezi 1993).

To address the afore-mentioned problems, most African governments have demonstrated a lot of political will and support for energy sector reforms, by developing energy sector policies to provide a focused framework on the key areas of concern to which the energy sector development must be directed.
According to Bacon and Besant-Jones (2001), Bacon (2001)[7], Karekezi and Mutiso (1998), the reforms in African countries have generally been designed to address the following issues:

i. Poor performance of the state-owned energy sector with respect to sub-optimal costs, inadequate expansion and access to electricity and other energy services, poor quality of service delivery
ii. Inadequate capital investment by governments, leading to the deterioration of infrastructure
iii. To allow private sector participation in the provision of energy sector

[6] Mkhwanazi, X. (2003) is of the view that non-optimal utilization of the energy resources can partly be attributed to the absence of local demand and lack of suitable transport infrastructure.

[7] Presentation by Dr. Robert Bacon of the World Bank on "The State of Power Sector Reform in Sub-Saharan Africa", in Nairobi, Kenya in April, 2001, and published in AFREPREN Occasional Paper No. 5, pp. 18-20.

iv. To allow the charging of efficient and economic cost-recovery prices and removal of subsidies
v. To raise revenue for government through disposal of state-owned assets
vi. To promote energy conservation and efficiency
vii. Improve accessibility to electricity, through a focused rural electrification policy
viii. Encourage inter-connection to neighbouring countries as a way of reducing the high cost of supply, through economies of scale

The reforms of the power sector therefore starts from a market structure that is dominated by a state-owned national power utility with a legally endowed monopoly (Karekezi et al. 2001) and a vertically integrated supply chain comprising power generation, transmission, distribution and customer services (Bacon and Besant-Jones 2001)[8]. These state-run utilities had no managerial autonomy to take decisions based on economic efficiency considerations without political interference, and by mid-1990, most decisions were actually made by the sector ministries (Karekezi and Mutiso 1998; Bhagavan 1999). Karekezi and Mutiso (1998) noted that in the mid-1990's, the government determined personal salaries for Tanzanian's state-owned utility called TANESCO, took all investment and tariff decisions. In Zambia, it was the Minister of Energy who approved the tariffs, investment plans and the budget for the utility company (Dube 1998). The level of political interference in the operations of African electric utility companies was observed in Ethiopia between 1974-1992, when the actual supervision and decision making of the Ethiopian Electric Light and Power Authority (EELPA)[9], rested with the Ministry of Mines and Energy (Taferra 2004). The Ministry of Mines and the central government was in charge of making decisions and seeing to the implementation of power sector development (Lemina and Wondimu 1996).

The level of political interference in Africa's power sector was criticised by the World Bank because it believed that managerial autonomy was critical to good investment

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**8** According to IEA (2002), the ultimate objective of the reforms should be an industry structure which encourages sufficient number of players to compete on equal terms, with the monopoly power of the established state-owned entities truly constrained. IEA (2002) however concede that while that is feasible in most developed countries, this may be an unrealistic early objective in the developing world.

**9** As part of the power sector reforms in Ethiopia (through commercialisation/corporatization), EELPA was replaced by the Ethiopian Electric Power Company (EEPCO), as a public, commercial entity by a Ministerial Council Regulation.

and operating decisions by the utilities, which should be based purely on economic efficiency (ESMAP 1996). The electric utilities must be able to adopt efficient operating procedures, contract out services whenever economic to do so, make investment decisions based on cost-benefit and least cost principles and enter into joint ventures or form partnerships with the private sector if necessary (Karekezi and Mutiso 1998). This level of autonomy and degree of flexibility will ensure that management can be held accountable for their decisions while attempting to achieve the enterprise performance goals (ESMAP 1996).

Under state ownership, prices were set to levels that could not cover investment needed to meet growing demand (Kessides 2004). Governments at some stage could no longer cope with the high costs of utility inefficiencies, stopped significant investment[10] in the electricity sector, which affected service coverage rate. The inability of utility companies to mobilise sufficient investment capital for electricity sector development meant that the choice was between rationing electricity supplies, and embarking on comprehensive reforms (Karekezi and Kimani 2000)

## 1.2 Need for Restructuring

The lack of adequate internal funding, mismanagement and poor operating practices have resulted in maintenance backlogs that adversely affected plant performance and network availability (Karekezi and Mutiso 1998; Karekezi et al. 2001; International Energy Agency 2002; Wamukonya 2003). In developing countries, publicly owned utility companies suffered from low labour productivity, deteriorating fixed facilities, poor service quality, high system losses, non-cost recovery tariffs, service unavailability to large portions of the population and inadequate investment (World Bank 1994; Bacon and Besant-Jones 2001). In the early 1990s for example, developing countries incurred annual losses of US$180 billion due to low pricing and technical inefficiency in the infrastructure sector (World Bank 1994).

To deal with the problem of lack of funding, low private sector participation and overall low sector efficiency, African governments were compelled to put in place favourable legal and regulatory reforms, strengthen the role of the independent

[10] African governments have traditionally guaranteed the financing of power sector investments in the past.

regulatory agencies and encourage realization of regional integration energy projects (Economic Commission for Africa 2003).

The catalysts for the power sector reforms in Africa and most developing countries are therefore due to economic and financial concerns (International Energy Agency, IEA, 2002), as well as donor conditions for further financial support to the sector (Wamukonya 2003)[11]. IEA (2002) and Bhagavan (1999) however caution that in carrying out the reforms, proper thinking and innovative sequencing of events are very crucial for successful reforms[12]. Table 1.1 below, lists some examples of countries and conditions which must be satisfied for IMF lending, for borrowing countries in Africa.

**Table 1.1 Conditions for International Monetary Fund (IMF) lending**

| **Country** | **Letters Of Intent Date** | **Key Reform Area** |
|---|---|---|
| **Benin** | 26/12/00 | Privatisation strategy for water and electricity utility to be decided by January, 2001. Privatisation to be completed before the end of third quarter |
| **Burkina Faso** | 17/4/00 | Waiver requested for the completion of the privatisation of the electricity company, SONABEL |
| **Cameroon** | 6/12/00 | Successful bidders for the electricity company, SONEL, to be selected by February, 2001. |
| **Cape Verde** | 26/4/99 | Privatisation receipts expected in the second half of the year from various public enterprises, including the electricity company |
| **Central African Republic** | 15/12/00 | Government plans to speed up the implementation of structural reforms with technical and financial assistance from the World Bank. The energy sector is |

[11] Part of the loan extended to reforming countries is earmarked for commercialisation or effectively restructuring power utilities to make hem attractive to the private sector. See details Wamukonya, N. (2003), "African Power Sector Reforms: Some Emerging Lessons", UNEP Collaboration Centre on Energy and Environment, Roskilde, Denmark.

[12] International lenders and major financial institutions have learned many new lessons the 'hard way', and most major lenders have switched away from energy projects to energy programmes, with sector reforms now aimed at paving the way for private sector participation. Major lenders are now emphasising proper sequencing of reform steps, which is expected to vary from country to country. More discussions can be found in: IEA (2002), "World Energy Outlook 2002: Energy and Poverty"

| | | |
|---|---|---|
| | | one area where there are ongoing operations to privatise or restructure companies |
| **Chad** | 6/7/00 | Negotiations on the privatisation of the management of the water and electricity company, STEE, began in the third quarter of 1999 |
| **Republic of Congo** | 3/11/00 | A management contract to be signed by June 2001 for the Société Nationale d'Electricité (SNE) electricity company. |
| **Ethiopia** | 29/1/01 | The restructuring of the telecommunications and electricity utilities will be finished, regulatory frameworks put in place, and decisive progress made with private participants in these activities in 2001/2002 |
| **Ghana** | 25/6/00 | A sales advisor for the Electricity Company of Ghana (ECG) to be appointed by the end of September 2000 |
| **Guinea** | 6/12/00 | An action plan for restructuring the energy sector should be prepared by the end of the year, under which the liquidation of the electricity company, ENELGUI, will be launched |
| **Guinea-Bissau** | 3/11/00 | The government will: (1) open financial bids for a long-term leasing contract (contract d'affermage) of the power and water utility, EAGB, by November 15, 2000 (2) create an independent regulator agency by end of January, 2001 |
| **Lesotho** | 12/2/01 | A private company to take over the management of the Lesotho Electricity Corporation (LEC). The management company will restructure and prepare the enterprise for privatisation in mid-2002. |
| **Mali** | 11/8/00 | The final call for bids to privatise at least 60% of the capital of Electricité de Mali was launched in August 2000. |
| **Mauritania** | 25/5/00 | The sale of 49% of SONELEC'S electricity component to a strategic partner was deferred to March 2001, when the entire responsibility for managing the company will be assumed by the strategic partner |
| **Niger** | 21/11/00 | The terms and conditions for the privatisation of |

| | | |
|---|---|---|
| | | NIGELEC electricity were finalised, with a concession arrangement for the generation, import and distribution of electricity |
| **Senegal** | 4/6/99 | Government shares in six large enterprises including the electricity company, SENELEC, were scheduled for sale in 1999 |
| **Uganda** | 21/8/00 | Government approved legislation in November, 1999, to remove the state monopoly, establish an independent regulatory agency and unbundle the Ugandan Electricity Board (UEB) into separate distribution, transmission and generation companies. |
| **Zambia** | 30/6/00 | Elimination of government majority ownership of the electric utility, ZESCO. |

**Source: Wamukonya (2003), published in Energy for Sustainable Development, Volume 7, No.1, March 2003.**

Restructuring, privatisation and regulation reforms have made network utilities to be more efficient in developing and transition economies, due to policy options previously denied to state enterprises (Kessides 2004).The reforms are expected to ensure adequate, reliable, efficient and price competitive provision of electricity in countries of rapidly increasing demand. The creation of a regulatory framework as one of the main components of the reform is expected to put the necessary mechanisms in place to oversee the sector and set targets towards the attainment of overall sector objectives. The reform process involved the following:

i. Privatisation and Public-Private Partnerships
ii. Introduction of competition, where feasible
iii. Undertaking regulatory reforms

The research study therefore is an effort to carry out econometric assessment of the effects of power sector reforms comprising privatisation, competition and regulatory reforms in Africa for the period 1988-2005, using panel data analysis. It is hoped that the results of the study will go a long way to assist African governments to formulate power policies aimed at making the power sector more viable and financially sustainable, while enhancing the overall efficiencies in the industry.

### 1.3 Motivation

The extent and pace of the power sector reforms in most developing countries have generated significant controversy, and in most cases, the reforms have been followed by major electricity tariff increases that have resulted in protests from consumers (Karekezi et. al 2001). Although some outcomes have been disappointing, there have been substantial, but always obvious gains (Kessides 2004).

The pessimists have argued that in most African and Latin American countries, electrification is not complete and there is a system size below which vertical separation and competition is not effective and worthwhile (Jamasb et. al 2005). This assertion seem to be supported by Borenstein (2002)[13] and Smith (2002), when they stated that privatised and, or deregulated power industries, are more susceptible to failures in the presence of capacity constraints. According to Dagdeviren (2007)[14], evidence seem to suggest that even in advanced countries, full or competition in the power sector is impracticable, and argues that intuition will suggest that it would be harder for similar reforms to work well in developing countries.

The above arguments against power sector reforms in developing countries, seem to have found support also from Hunt (2002) and Yi-Chong (2005) who argued that the integrated model in the United States of America and other places are now being praised for its reliable supply, low prices and universal access. Daunting failures like California, Alberta and Ontario during 2001-2003, are believed to hold back the aggressive efforts for privatisation and reforms in developing countries (Dagdeviren 2007),

The above arguments against the reforms have been opposed by Bessant-Jones and Tenenbaum (2001), when they argued that using the California power crisis and other associated problems, to prove that undertaking the reforms is too risky is incorrect. They further argued that for developing countries, maintaining the status

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[13] Detailed discussions can be found in Boreinstein, S. (2002). "The trouble with electricity market: Understanding California's restructuring disaster", Journal of Economic Perspectives, 16(1), pp. 191-211

**[14]** See details in Dagdeviren, H. (2007). "Privatisation of electricity and water – Is it still worthwhile?" Global Poverty Research Group, and Brooks World Poverty Institute Conference, University of Manchester.

quo in the power sector is the riskiest. This can impact negatively on economic growth through inadequate and poor quality of service. They supported their argument by stating that “like all human endeavours, power sector reforms can be done well or poorly”. What matters according to Bessant-Jones and Tenenbaum (2001) is that, the reform must focus on the starting point, identify the specific problems that need to be solved, as well as the appropriateness of the path selected for solving these problems.

In assessing the results of reform outcomes, Kessides (2004) cautions that assessment can be complicated by the brief history of privatisation, restructuring and regulatory reforms in developing economies, and by severe measurement problems for crucial economic variables. These difficulties not withstanding, most empirical evaluations of privatisation and restructuring seem favourable (Gray 2001; Megginson and Netter 2001). Most of the empirical studies to date have generally pointed to economic gains from privatisation, and that failure or success actually depended on post-privatisation regulation (Levy and Spiller 1996; Bortolotti, Siniscalco and Fantini 2000; Jamasb and Pollitt 2000; Arocena and Waddams-Price 2002).

Lack of empirical knowledge has also been cited as one of the main barriers to infrastructure policy analysis and reform in developing and transition economies (Kessides 2004). Kessides (2004) believes that empirical studies can put the pessimists in a better position to reflect on lessons, and identify the most important issues which need to be addressed.

In the light of the above arguments for and against the power sector reforms, particularly in the developing countries, it is imperative that the actual impact of the reforms are analysed empirically, and not limited to a theoretical debate or to a qualitative approach. Though empirical and econometric studies of the impact of power sector reforms exist for OECD and advanced countries, most econometric studies for developing countries have been concentrated on Latin America countries, with emphasis on Chile and Argentina (Lalor and Garcia 1996; Chisari et al 1999). This assertion is further reinforced by Zhang et al. (2002) when they stated that “there is a lack of empirical study which covers the effects of privatisation, competition and regulation” for developing countries.

## 1.4 Thesis Objective

The primary objective of the thesis is to carry out an econometric assessment of the effects of power sector reforms in African countries for the period 1988-2005, using panel data analysis. It is worthy to note that Eberhard (2005)[15] has carried out non-econometric case studies on African countries. Another empirical but non-econometric study, was carried out by Estache et al. (2007). Their study focused on twelve countries in the Southern African Power Pool (SAPP), over the period 1998-2005[16]. This thesis is expected to fulfil the following key objectives:

a. to increase the body of knowledge on Africa's power sector by providing a comprehensive and systematic data base for future empirical work on Africa's electricity sector.
b. establish the relevance of using regulatory index for policy debate
c. measure the impact of reforms on key performance indicators in the generation, transmission and distribution sectors.

## 1.5 Hypothesis

A priori, reforms are expected to provide clearer objectives to utility management, to lead to higher efficiency. The creation of regulatory bodies to operate at arms-length from governments is expected to enhance the economic regulation and pricing for the electric utilities. It is also expected that introduction of competition or private sector participation in the generation segment will serve as a catalyst for cost reduction and expansion of services. The hypotheses for the study have been formulated to cover the three segments of the Electricity Supply Industry as follows:

[15] Eberhard (2005) carried out non-econometric case studies to ascertain whether utility regulators in Africa have been able to facilitate an appropriate balance between development and investment outcomes. Details of the results of the studies can be found in Eberhard, A. (2005). "Regulation of Electricity Services in Africa: An Assessment of Current Challenges and an exploration of new regulatory models", A paper prepared for the World Bank Conference towards Growth and Poverty, University of Cape Town, South Africa.

[16] Estache et al. (2007) measured the economic efficiency in African electricity distribution, by estimating the productivity change using Malmquist Total Factor Productivity Index,

1. **Generation Sector**

   a. Regulation will increase installed generation capacity, plant utilization and actual plant output

   b. In the presence of regulation, private sector participation in generation, will increase installed plant capacity and actual plant output

   c. Competition ‘for’ the market or private sector participation in generation, will lead to higher plant utilization and higher plant output.

2. **Transmission Sector**

   a. The co-existence of Energy Sector Law and regulatory agency, will lead to reduction in transmission system loss level.

   b. The existence of a regulatory agency will reduce transmission network loss level

3. **Distribution Sector**

   a. Energy Sector Law and presence of autonomous regulation will lead to reduction of total distribution system loss level.

   b. Private Sector Participation will lead to lower total distribution system loss level.

## 1.6 Approach and Research Technique

Primary Information for the research study was obtained from the following:

i. Specially designed questionnaire to obtain the following information from the countries which form the research sample:

   - Legal and Regulatory Framework
   - Industry Structure
   - Price Regulation
   - Generation System Data
   - Transmission System Data
   - Distribution System Data

Details of the questionnaire are attached to this thesis as Appendix 1. Information from the questionnaire was supplemented with secondary data from the following sources:

ii. The World Bank Development Indicators

iii. United States Energy Information Agency

iv. Academic books, articles and reports from energy sector experts from the following:

- The World Bank and International Monetary Fund
- The African Forum of Utility Regulators (AFUR)
- The African Energy Policy Research Network (AFREPEN)
- Regulatory bodies and regional regulatory associations
- Public Utilities Research Centre, University of Florida, USA.
- The Institute for Public-Private Partnership (IP3), USA.

v. Economic Freedom of the World Report, 2006

vi. Political Constraint Index (POLCON) Report, 2006

The empirical analysis was carried out using panel data econometric and was organised as follows:

i. Postulating the hypothesis to be tested for the generation, transmission and distribution segments of the Electricity Supply Industry

ii. Definition of the relevant performance indicators (i.e. dependent variables)

iii. Definition of explanatory or independent variable, as well as identification of relevant control variables

iv. Definition of baseline econometric model

v. Extension of baseline model to include other control variables

vi. Carrying out econometric analysis for both static and simple dynamic models

## 1.7 Research Contribution

### 1.7.1 Creation of reliable database

One of the expected positive effects of the research is that it will serve to establish a comprehensive and expanded data base on the electricity sector for African countries for the entire electricity supply industry (i.e. generation, transmission and distribution sectors). Lack of empirical knowledge seems to be the main hindrance affecting infrastructure policy analysis and reforms in most developing and transition economies (Kessides 2004). Kessides (2004) further argues that since most reforms started in the early 1990s, until recently, there were not enough data to carry out detailed evaluation of different ownership, structural and regulatory options.

In that regard, this study will attempt to develop a reliable database, to make data available for future empirical studies on Africa's electricity sector. It is expected that this would assist to increase the body of knowledge on the status of the continent's electricity sector reforms.

### 1.7.2 Decomposition of Regulatory Framework Index

One reform variable, which requires some enhancement on how it has been measured in most previous empirical studies, is the degree of regulatory effectiveness. In the absence of a good indicator, researchers have adopted very simple measures of regulatory effectiveness, but this approach it has been observed, does not appear to satisfactorily assess the formal and informal aspects of regulation. This observation was corroborated by Brown et al. (2006) who noted the following three weaknesses in earlier regulatory evaluation studies:

i. The earlier studies have focused almost exclusively on the institutional and legal attributes of regulatory systems
ii. the evaluations do not carry out detailed analysis to ascertain whether the formal legal requirements have actually been implemented
iii. the studies do not attempt to establish any link between the regulator's actions or decisions and sector outcomes

From the economics literature, it was noted that Gutiérrez (2002) constructed a 7-element regulatory index for the telecommunications sector. Cubbin and Stern (2005) also constructed a 4-element index for the formal attributes of regulatory governance. Zhang et al. (2005) produced a 4-element regulatory governance index for use as one of the key variables in the econometric analysis. A critical look at the factors used however shows that the index only measured the formal aspects of regulation. Montoya and Trillas (2006) also computed three indices namely IR1, IR2 and IR3 to measure (de jure) independence of Telecommunications Regulatory Agencies, of twenty-three Latin American countries over the period 1990-2004.[17]

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[17] In the study by Muntoya and Trillas (2005), IR1 was used to measure regulatory independence based on the methodology of Gual and Trillas (2004 and 2006). IR2 was computed based on Edwards and Wavermann (2006), while IR3 was based on the methodology of Gutiérrez (2003). See details in

Zhang et. al (2002) and many authors that have studied the impact of reforms have acknowledged the limitation of the use of 0/1 dummy variable to capture the effectiveness of independent regulatory structure, (where 1 represents the existence of a regulatory body and 0 otherwise). This approach is not only too simple, but fails to critically assess both the formal (i.e. legal attributes of regulation) and informal aspects (i.e. regulatory practice and content) of regulation. Zhang et al. (2002) therefore recommended that further research efforts are needed to develop more robust measures of electricity reforms in developing economies.

This research is thus expected to make a contribution to the literature by attempting to model a regulatory framework index for each country in the research sample, by decomposing the index into *formal and informal regulatory indices,* for use as key independent variables, in the econometric analysis,

### 1.7.3 Use of time-dimensioned variables

Most econometric studies adopted simplified approaches to represent the key reform variables in the econometric models. For privatisation and regulation[18], the usual approach has been the use of 0/1 dummy variable and for competition, 0/1 dummy has also been used to gauge the degree of opening of markets to full or partial competition, where 1 is assigned for the occurrence of the event and zero otherwise [19]. Although such methodology may be acceptable in standard econometric modelling, this is not likely to yield robust econometric estimates because the switch from 0 to 1 in most cases is not dated or time-dimensioned. This is a gap which has been identified in the economics literature and an attempt would be made to improve upon this approach, by ensuring that all the variables for the econometric analysis are time-dimensioned.

### 1.7.4 Scope of econometric analysis

Another unique characteristic as well as an original aspect of the study, is that the econometric analysis will cover all the three segments of the electricity industry (i.e. the generation, transmission and distribution sectors). To achieve this objective, the

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Muntoya, M. and Francesc, T. (2006). "The Measurement of the Independence of Telecommunications Regulatory Agencies in Latin America", Autonomous University of Barcelona, Spain.

**18** Gutiérrez (2002, 2003) used a time dimensioned variable to construct a regulatory framework index for Latin American countries in the Telecommunications sector, See also Gutiérrez and Berg (1999)

**19** For example, see Zhang et al. (2002), Wallsten (2001) hypotheses have been carefully formulated, and the dependent variables for the econometric analysis, have also been carefully selected, to reflect the expected reform outcomes in the three segments of the industry.

Estimating the impact of electricity losses separately on the transmission and distribution systems appears to be missing in most previous econometric studies[20]. There is no doubt that one of the main goals of electricity sector reforms is to improve quality of network efficiency by reducing system losses, particularly distribution system losses. The research will attempt to capture the separate impact of the reforms on total distribution and transmission network losses.

### 1.7.5 Policy and Regulatory Implications

The research study is also expected to guide power sector reformers and regulators on the right approach to adopt to ensure the success of the reforms. The study is also expected to aid policy makers to better compare the performance of public and privatised electricity generation and distribution companies. The conclusions will also guide policy makers on the impact of the regulatory framework on the efficiency of African utility companies and also measure the impact of regulatory framework on utility performance. The empirical results are expected to provide inter alia, answers to the following critical policy questions:

i. Is competition the key driver of the performance of the utility companies?
ii. Will privatisation alone achieve the desired results or it must co-exist with other reform variables? What strategies should governments that are reforming the electricity sector and pursuing privatisation adopt?
iii. Will introduction of private sector participation stimulate investment in generation and distribution sectors of the Electricity Supply Industry (ESI) to enhance economic performance?
iv. What is the appropriate market structure for non-sophisticated electricity markets in Africa? What is the best model of privatisation and how far can it employed to the maximum extent possible?
v. Will presence of regulatory agency provide different incentive levels for improving utility performance?

[20] Econometric analysis by Cubbin and Stern (2005, 2006) covered combined technical distribution and transmission losses.

These questions are very important considering the fact that power sector reform is a politically challenging one. The politics of reforms is not only limited to the sector restructuring but most important, to the creation and maintenance of a conducive environment, which will permit investment to be made to meet the growing population demand.

## 1.8 Thesis Outline

The rest of the thesis is structured as follows:

The literature review is presented in chapter 2 while chapter 3 describes in detail, the data collection methodology and key elements of the research questionnaire. Chapter 4 examines the proposed methodology for constructing the regulatory framework index, and presents the final results of formal and informal regulatory indices. In chapter 5, the dependent and independent variables for the econometric analysis are identified and defined for the generation and network sectors. The results from the econometric estimations are critically analysed and discussed in chapter 6, while final discussion and conclusions are presented in Chapter 7.

# CHAPTER 2 LITERATURE REVIEW

## 2.1 Introduction

Although econometric and other empirical evidence of the power sector reforms exist for advanced and industrialised countries, with the exception of few case studies, the impact of the reform experience in developing countries, especially in Africa has not been well-researched. Few studies on developing countries have only been concentrated on Latin American countries (Lalor and Garcia 1996). Research work has revealed that generally, there exist very few preliminary studies such as Zhang, Kirkpatrick and Parker (2002), Pargal (2003), Cubbin and Stern (2005) and Zhang, Kirkpatrick and Parker (2005). The section reviews the various empirical approaches for assessing the impact of electricity sector liberalisation. For ease of discussions, this section is sub-divided as follows:

i. Effects of reforms variables on key performance indicators
ii. Determinants of reforms and key steps
iii. Productivity and efficiency studies

## 2.2 Effects of reform variables on performance indicators

One of the few studies that examined the impact of reforms in developing countries was by Zhang, Parker and Kirkpatrick (2002). The study carried out an econometric assessment of the effects of privatisation, competition, and regulation on the performance of the electricity generation sector using panel data for 51 developing countries over the period 1985-2000. The study specifically sought to identify the impact of the reforms on generating capacity, electricity generated, labour productivity as well as industrial and residential prices.

On privatisation, they hypothesised that privatisation will lead to:

i. Higher operating efficiency and higher capital utilisation
ii. More capacity and hence higher output, provided that the regulatory regime is supportive of investor confidence
iii. Higher prices to residential customers and lower prices to industrial users, as prices are aligned with marginal costs

On Competition, Zhang et al. (2002) formulated the hypothesis that competition will lead to:

i. Larger capacity, higher output and greater labour productivity
ii. Lower industrial user prices and would either raise or lower residential user prices

Regarding the effects of regulation on electricity sector reforms, Zhang et al. (2002) put forward the following hypothesis:

i. Independent regulation in place of direct government department regulation, will improve productive efficiency
ii. Independent regulation will raise prices charged to domestic consumers as cross-subsidies are removed

One of the main drawbacks of the study is the use of 0/1 dummy for the key variables (i.e. privatisation, competition and regulatory reforms) which were not dated and therefore fail to capture the intensity of competitive pressure faced by incumbents, as well as the share of private capital in the generation sector, thus creating the problem of omitted variables. For instance the use of 0/1 dummy for privatisation will classify a leading electricity reformer like Argentina in the same category as a latter reforming country like Bulgaria (Jamasb, Mota, Newberry and Pollitt 2005).

Zhang et al (2002) also admitted that the use of 0/1 dummy variable for regulation was particularly crude and could not reflect the effectiveness of the various forms of regulation, which was adopted by the various countries in the sample. They therefore suggested that future similar research work should focus on developing more robust measures of electricity reforms, through the use of better data and detailed studies, to gauge the effectiveness of the regulatory practice and processes.

The above drawbacks notwithstanding, the empirical results of Zhang et al. (2002) seemed consistent with the findings of similar studies to assess the importance of competition and/or effective independent regulation. Specifically on privatisation, the study rejected the hypothesis that privatisation will lead to higher operating efficiency. This result is consistent with what pertains in the economic literature that competition rather than the ownership change is the key to performance improvement. The study also supported the idea that the generation capacity utilisation does not improve under privatisation, independent of competition and regulation. The results also suggested that privatisation, when linked with competition and/or regulation does not have a statistically significant effect on residential and industrial user prices.

With respect to the competition hypothesis, the econometric results supported the view that competition will lead to higher generating capacity per capita and a higher labour productivity. On prices, the results of competition was ambiguous in that competition does seem to lower industrial prices, but this result is reversed when competition is interacted with regulation. Zhang et al. (2002) also found out that competition does not necessarily lead to efficient capacity utilisation. This they explained can possibly be due to entry of competitors to expand generation capacity to cause a reduction in the system average generation utilisation.

One feature of the result is that privatisation alone does not appear to improve labour productivity, but when interacted with independent regulation, there was a significant and a positive effect. The study rejected the hypothesis that regulation will raise domestic consumer prices as cross-subsidies are removed. Regulation was found to have no impact on industrial prices, although when interacted with competition, industrial prices were found to be higher. Though the results were generally consistent with those from similar studies, it failed to address the problem of simultaneity and used simple 0/1 dummy variables to measure the key reform variables.

In order to address the short-comings of the study by producing better measures of regulation, competition and privatisation, Zhang et al. (2005) undertook another study to investigate the effects of regulation, competition and privatisation using panel data econometrics, for 36 developing and transitional countries for the period 1985-2003. In the 2005 study, they constructed the privatisation variable as a percentage of generating capacity owned by private investors, while the competition variables was constructed based on the largest market share of the largest generators in the sector. For regulation, they constructed a 4-element regulatory governance index comprising: (i) whether there is an electricity or energy sector law (ii) whether the regulator claims to be independent (iii) whether there is fixed term of appointment for the head of the regulatory body (iv) whether the regulator is financed through fees and levies. The main conclusion of the Zhang et al. (2005) study was that in developing countries, performance improvements in electricity generation are assured when competition or independent regulation is instituted.

Cubbin and Stern (2005) carried out an assessment of good regulatory governance on electricity industry capacity and efficiency in 28 developing countries, including four African countries[21], over the period 1980-2001. The focus of their empirical research was on regulatory governance rather than regulatory content. In their study, Cubbin and Stern (2005) hypothesised that:

i. The presence of an effective regulatory framework in a developing country will lead to increase in investment (local or foreign) in the electricity sector.

To estimate the impact of regulatory effectiveness, they focused on the following:

i. Electricity capacity levels, which were proxied by rated generation capacity per capita
ii. Efficiency measures in developing countries, which were also proxied by capacity utilisation of generation and assessment of transmission and distribution technical losses.

In providing justification for the performance indicators used in the study, Cubbin and Stern (2005) agued that once effective regulation is present to support a feasible financial framework, investment is encouraged and private investors have the prospect of earning a reasonable return on their investment. It is expected that the presence of an effective regulatory regime will encourage the growth of private investment and other private finance within state systems.

In their study, Cubbin and Stern (2005) operationalised the effectiveness and quality of regulatory governance by using the following four-element regulatory index:

i. Whether the country has an electricity or energy regulatory law
ii. Whether the country has an autonomous or a Ministry regulator
iii. Whether the country's electricity regulator is funded from licence fees or out of government budget
iv. Whether staff of the regulatory body remuneration is decoupled from civil service pay levels.

Each element was measured by a 0/1 dummy, which implied that the highest governance score of 4 on the index is obtained by a regulator that possesses all the characteristics, afore-mentioned. The study went a step further to investigate the effect of age of the regulatory agency by ensuring that the date of switch from 0 to 1, is based on the date of enactment of the law.

[21] Kenya, Nigeria, Sudan and Uganda

Cubbin and Stern (2005) argued that the absence of purpose-designed data sets on which to carry out the econometric analysis similar to the one used in the telecommunications sector resulted in weaknesses in the data set. Some of the identified weaknesses include among others:

i. Limited data on privatisation
ii. Absence of limited cross-county data on efficiency
iii. Data on the formal aspects of regulation allowed for a 4-element index, instead of a 7-element index used by Gutierrez, for the telecommunication regulation index
iv. Limited time dimension for data on privatisation and competition
v. Potential omitted variable bias due to the inability to test for the inclusion of many potentially significant variables

Despite the weaknesses in the data set, the empirical results were generally robust. The main conclusion drawn from the study was that controlling for country specific fixed effects, regulatory effectiveness is positively and significantly related with higher per capital generation capacity levels and higher generation capacity utilisation factors (Cubbin and Stern 2005).

Steiner (2001) examined the effect of regulatory environment, liberalisation and privatisation on the performance in the generation segment of the electricity market for 19 OECD countries for 1987-1996, using panel data techniques, across countries and years. Specifically, the study was aimed at examining the impact of regulatory reform on efficiency and price, as well as the relative efficiency of different reform strategies. Steiner (2001) measured efficiency by capacity utilisation rate and amount of reserve margin, using panel data set to compare empirically the experience of 19 OECD countries over the period 1986-1996. Her main hypothesis was that liberalising regulation, restructuring and privatisation are expected to yield improved efficiency, lower industrial electricity prices and lower industrial-to-residential price ratio. One of the major drawbacks of the study was the lack of controls for institutions or for macroeconomic policy.

Though Steiner (2001) acknowledged that the analysis would aid in the assessment of the impact of regulation and industry structure on performance, she was of the view that the analysis could be enhanced by refining the regulatory indicators and finding a suitable proxy for quality and market power[22]. She also suggested that similar analysis should be extended to cover the distribution and the transmission segments of the electricity supply industry.

In her conclusions, Steiner (2001) noted that utilisation rate is positively and significantly correlated with privatisation, and unbundling transmission from generation. The results confirmed the reserve margin hypothesis, but the coefficient on unbundling of generation and transmission and third party access, were not significant. She however found that privatisation was not necessarily correlated with increased competition, but the impact of reforms on the price ratio showed the benefit of reforms to be skewed in the direction of industrial customers. She also found that the price discrimination can persist and even intensify under reform, if market power is not reduced by structural measures such as horizontal unbundling. This result is in line with the economic literature and also raises a serious political issue in many countries where large and bulk customers seem to disproportionately benefit from price-realignment towards efficient costs, which is normally associated with unwinding of cross-subsidies.

Unlike Steiner (2001), Hattori and Tsutsui (2004) carried out empirical research for the same 19 OECD countries for the period 1987-1999. They found the presence of an electricity wholesale market to be statistically significant and positive. The differences in the empirical results of Steiner (2001), and Hattori and Tsutsui (2004) are attributable to changes in the definition of the regulatory reform variables. While Steiner (2001) used a random effects model, Hattori and Tutsui (2004) used both random and fixed effects model. The key drawback in the two studies is the non-inclusion of time effects, which become relevant the longer the time series. Furthermore, the econometric models used did not solve the problem of endogeneity through the use of instrumental variables.

Holborn (2001) examined the effect of political risk on international expansion strategies of firms in electric power generation. Specifically, he tested the hypothesis that an individual firm’s entry to a particular market will increase with the degree of its previous experience on a similar type of market, as well as the risk of

[22] Steiner (2001) could not get a suitable proxy for quality, and since labour productivity is not a good measure of efficiency in a capital-intensive sector like electricity, she used reserve margin from ‘optimal’ reserve margins as a proxy for efficiency.

expropriation. He tested the hypothesis using a data set covering privately-financed power generation projects outside North America, spanning 10 years, 191 companies from 64 countries. A careful analysis of the econometric model show that though country, market and institutional conditions have been included, it fails to include important reform variables for regulatory reforms and type of industry structure.

The above weaknesses notwithstanding, Holborn (2001) observed that prior experience from similar market has a substantial impact on the probability of entry, but firms tend to concentrate on one type of market environment (i.e. competition or monopsony). He also found that while higher levels of political risk typically discourage entry, the impact is significantly lower for firms with greater levels of international experience.

Bergara, Henisz and Spiller (1997) tested the hypothesis that well-defined and credible political institutions are positively correlated with investment [23] in the electricity sector, for a sample of 91 developed and developing countries for only 1997. Though the results supported the hypothesis, there were serious unanswered gaps in the analysis. For instance, Bergara et al. (1997) did not include any post-reform data in the analysis, while the use of generation capacity as a proxy for investment creates a serious measurement problem because, the composition of investment between generation, transmission and distribution will vary significantly from country to country (Jamasb et al. 2004)

Siniscalco, Bortolotti and Fantini (2001) also carried out an empirical test to ascertain whether vertical integration will impact negatively on the number of privatisation , the aggregate proceeds of privatisation and on the percentage of privatised stock. They found that vertical integration was significantly negatively correlated with the number of sales and aggregate proceeds of privatisation, while the regulatory index was positively and significantly correlated with the number of sales and with privatisation proceeds.

### 2.3 Elements of determinants of reforms

One of the well-documented research studies on the determinants of reforms was by Bacon and Besant-Jones (2001). They used cross-section data on 115

[23] The main dependent variable used for the analysis was the log of public and private capacity per 1000 people.

developing countries[24].They tested the hypothesis whether country policy and institutions were positively correlated with reforms in the electricity sector, and whether country risk is negatively correlated with reform. A priori, one expects country policy and institution to be positively correlated with reforms, while political and economic risk is expected to be negatively associated with reforms.

Their result was consistent with economic literature where the coefficient on the policy indicator as well as the risk indication, is significant and has the expected signs. Despite the consistency of results with economic literature, some drawbacks have been noticed which tend to affect the robustness of the results. For instance, though Bacon and Bessant-Jones (2001) based the country policy and institutional assessment variable on 20 indicators, these indicators are not clearly identified (i.e. economic management and sustainability) and there is a possibility of the risk of co-linearity with the reform indicator. Though the hypothesis was specifically formulated to address electricity sector reforms, it is undoubtedly clear from the study that they refer to overall management of the economy and the public sector. The only variable specific to the electricity sector is the annual growth rate of energy use per capita (MWh per capita), which is an independent variable in the model.

Unlike Bacon and Besant-Jones (2001), Drillisch and Riechmann (1998) examined the relationship between energy dependency, environmental commitment and the choice of liberalisation model. Their study covered 13 countries[25], using cross-sectional data for 1995, The liberalisation index was measured using wholesale reforms (i.e. pool, wholesale wheeling or competitive bidding), timing of reforms and retail reforms (i.e. regulated third party access, negotiated third party access) and timing of retail reforms.. The key independent variables used were prices and energy independence index.[26]

[24] The main reform variable used was Reform Scores calculated from the number of reform steps taken by each country in the ESMAP (1999), comprising corporatisation, restructuring, existence of sector law, existence of a regulator, IPP entry and divestiture.

**[25]** The countries were: Australia, Germany, Denmark, Spain, France, Japan, Norway, Netherlands, New Zealand, Sweden, Finland, U.K. and USA.

**[26]** Calculated from total primary supply of each different fuel, total exports of each fuel, indigenous production of each fuel, share of each fuel in total electricity production.

Some of the drawbacks of the study are the non-inclusion of time effect in the model, though a temporal dimension is incorporated in the model, in the form of the impact of past decisions on energy and electricity dependency and environmental commitment. Another drawback is the narrow definition of liberalisation index which did not take account of such key variables like corporatisation, privatisation, restructuring, regulatory change and the presence of effective, credible and independent regulatory body.

Despite the afore-mentioned shortfalls, the results of Drillisch and Riechmann (1998) provide some interesting observations. They found a positive correlation between fuel import independence and liberalisation. The study also found that the estimated overall energy independence index to be much more significant than the electricity sector index. Results of the study did not however establish a significant inter-dependence between environmental commitment and the choice of liberalisation model.

Also, Ruffin (2003) carried out an econometric assessment of institutional determinants of competition, ownership and extent of reforms (i.e. dependent variable). He tested the hypothesis that judicial independence, economic ideology and distributional conflict influence competition. He also tested the hypothesis that judicial independence, economic ideology and distributional conflict influences private ownership. The study used a cross-section Ordinary-Least Squares (OLS) analysis for 75 developed and developing countries. The study finds that the relationship between judicial independence and competition and ownership is ambiguous i.e. insignificant coefficients, or when significant, their sign shifts across models. The results also suggested that greater distributional conflict was significantly correlated with a higher degree of monopoly, while the relationship between economic ideology in favour of competitive and private ownership, was generally positive and significant.

Estache and Rossi (2004) carried out an empirical study to examine whether increases in labour productivity have had any impact on lower prices for final consumers, by comparing the relative performance of public and privatised Latin American electricity distribution companies for 1994-2001. In the study, they used number of employees and capital input, measured by kilometres of distribution network, as the independent variable and three outputs namely number of final customers, total energy supplied to final customers and the service area (square metres) as the dependent variables. The main econometric model used was OLS, but in order to assess the robustness of the results, four alternative model specifications namely Stochastic Frontier Model, Model in First Differences and Operating and Maintenance Model, were also used.

From their results, Estache and Rossi (2004) concluded as follows:

i. Privatised firms are more labour efficient than their public counterparts. Private firms use about 30% to 45% less labour to produce a given bundle of outputs, compared to public firms
ii. Private firms operating under price cap and hybrid regulating schemes are more labour efficient than both public and private firms under rate-of-return regulation
iii. Private firms operating under Rate of Return regulation have at most, similar labour efficiency as public firms

Estache and Rossi (2004) however cautioned that the empirical evidence from the study should be interpreted with care, for it does not provide definitive conclusions about the effects of privatisation and incentive regulation, on the efficiency of electricity distribution firms in Latin America countries because of the problem of omitted variables. In that regard, they suggested additional research, to refine the assessment and to provide more reliable and robust estimates. They suggested that this should include collection of comparable data on quality of service and a longer period of analysis, instead of the 7-year period (i.e. 1994-2001) used for their study.

## 2.4 Productivity and Efficiency Studies

The second class of empirical studies looked at the effect of electricity sector reforms on productivity and efficiency levels achieved in the electricity sector. The main analytical approaches in the economics literature can generally be categorised as follows:

i. **Frontier Techniques**:
   a. Data Envelopment Analysis (DEA)
   b. Stochastic Frontier Analysis (SFA)

**ii. Non-Frontier Technique**
   a. Total Factor Productivity (TFP)

The frontier approaches generally seek to distinguish between technical change (i.e. efficiency frontier shift) and efficiency change, which measure the move towards the efficiency frontier (Diewert and Nakamura 1999; Sarafidis 2002; Jamasb and Pollitt 2003). DEA technique is a non-econometric approach, which uses linear programming method to determine the efficiency frontier, while SFA is an econometric method for estimating the efficient frontier (Farrel 1957; Färe et al. 1985; Coelli et al. 1998; Sarafidis 2002; Farsi and Filippini 2005[27]). TFP is used to calculate the factor productivity index using an output/input index (Coelli et al. 1998; Cambridge Economic Policy Associates 2003). Unlike DEA and SFA, the final efficient index in TFP cannot be decomposed into technical or allocative efficiencies (Coelli et al. 1998).

Plane (1999) used SFA to assess the impact of privatisation of Cote d'Ivoire Electricity Company (CIE) on efficiency and on the welfare distribution. This was a single country study and in the basic model, gross generation (Gigawatt-hours) was used as a function of installed capacity (Megawatts), and the number of permanent employees. The base model was later on enhanced to include variables like ratio of customers to length of distribution network, and a dummy variable for privatisation. The results supported the hypothesis of sufficient performance improvement in the post-privatisation period. With respect to welfare distribution, the results indicated that consumers benefited through a substantial price reduction, enhancement of quality of electricity supply, while electricity coverage increased by over 16%.

Considering the fact that there was no restructuring, privatisation or divestiture, and since the only change was a management contract, the author argued that the improved benefits emanated from decentralisation, reduction of hierarchy of reporting layers and managerial incentives. He however cautioned that the achievements by the utility company should not be divorced from achievements of the overall macro-economic stability through re-alignment of exchange rate regime in Cote d'Ivoire. DEA and SFA have been used in the economics literature for

[27] The non-parametric approaches such as DEA and others are considered to be a deterministic function of the observed variables and require that no specific functional form is imposed. The parametric methods allow for random unobserved heterogeneity among different firms and also require the specification of a functional form. See further details in Farsi, M. and Filippini, M. (2005), "Analysis of Electricity Distribution Utilities in Switzerland", Centre for Energy Policy and Economics, Department of Management Technology and Economics, Swiss Federal Institute of Technology, Switzerland. See also Affuso et al (2002) for further discussions.

benchmarking and efficiency analysis in the electricity sector particularly in Great Britain, the Nordic States and Austria. Jamasb and Pollitt (2003) performed an international benchmarking of 63 utility companies from 6 European countries by comparing several SFA and DEA specification. Their main conclusion was that the efficient frontier was populated by smaller utilities than the U.K. firms.

Pollitt (1995) used DEA for 136 US firms and 9 U.K. firms. He found that there was no strong evidence that ownership affects performance of utility companies. This result was reinforced by the empirical work of Scarsi (1999), who carried out an analysis of technical efficiency of two local electricity distribution companies in Italy for 1994 and 1996, using Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA). In the econometric results, he found no statistically significant difference between private and publicly owned firms.

Hjalmarsson and Kumbhakar (1998) undertook a study of the Swedish electricity distribution utilities for the period 1987-1990. The main objective of their study was to examine whether ownership or organisation of the distribution companies has any systematic impact on economics of scale, technical change and relative efficiency in labour, across different ownership categories.  They found that in the SFA models, municipal utilities were more efficient than mixed ownership firms, while the opposite was the case in the DEA models. Hjalmarsson and Kumbhakar (1998) interpreted the strong efficiency differences between private and publicly owned firms, as strong indication of the impact of indirect competition present in the market.

Arocena and Waddams-Price (2002) also studied the impact of regulatory reforms on 33 publicly and privately owned coal-fired electricity generation plants in Spain, for the period 1984-1997, using Malmquist DEA. In their study, they used generation capacity (Megawatt), number of employees and volume of fuel as the inputs, while the output consisted of energy output (Megawatt-Hours) and declared plant availability. The conclusions from the study showed that public generators are generally more efficient under cost-of-service regulation, while private generators catch-up and overtake the public sector generators under price cap regulation, by responding to incentive regulation through increase in efficiency.

In another study, Delmas and Tokat (2003) assessed the short-term impact of supply deregulation on the productive efficiency of electric utilities in the USA , as well as the relationship between the level of vertical integration and efficiency in a de-regulated environment. They analysed the short-term impact of retail deregulation on the productive efficiency of 177 investor-owned electric utilities in the United States, from 1998-2001. They used a DEA technique to determine the efficiency scores and a Tobit model to test the following two hypotheses:

i. In the short term, the level of deregulation will vary inversely with the level of technical efficiency
ii. There exists a parabolic relationship between the level of vertical integration and efficiency.

The study used Operating and Maintenance, Capital Cost and Cost of Electricity produced as the input variables. The volume of energy sales (MWh), discriminated by customer type served as the output variable. The results show that the process of deregulation has a negative impact on firms' productive efficiency, measured using DEA. They also observed that firms that are vertically integrated into electricity generation, or that rely on the market for the supply of their electricity are more efficient than firms that adopted hybrid structures, comprising vertical integration and contracting.

Though the results of the study supported the two hypotheses, the model suffered from the following weaknesses:

i. The limited time span of the study
ii. No control variables for economic changes and other characteristics like urbanisation or customer density are included
iii. A lot questions have been asked concerning the use of DEA technique to carry out the analysis, since DEA is known to be best suited for comparing similar activities and technologies
iv. The use of second stage Tolbit regression on DEA scores is generally performed for the purpose of adjusting the efficiency scores for factors that are beyond the control of utility management.

A similar study by Rodriguez-Pardina and Rossi (2000) used Stochastic Frontier Analysis (SFA) to study the technical change in 36 electricity distribution companies in South America (1994-1997), with the view to setting the efficiency or X-factor for use in a price-cap (i.e. RPI – X) price regime. In their study, the number of connected customers was the dependent variable, while distribution network length, number of employees, service area, transformer capacity, percentage of sales to domestic customers, total sales and an interaction variable between time and reform dummy, served as the independent variables. Their results supported the hypothesis of no change in inefficiency over the study period. They also found evidence of partial correlation between reforms and performance.

Filipinni (1998) and Filippini and Wild (2001) used SFA in a productivity study of 39 and 59 Swiss electricity distribution utilities respectively. The results of both studies showed that regional differences in service territory significantly influence productivity. One interesting aspect of the result is the identification of significant economies of scale such that smaller utilities can reduce costs by merging and thus extend their sub-optimal service territory size.

Rossi and Ruzzier (2001) and Estache et al. (2002), used DEA and SFA[28] on 39 electric distribution utilities between 1994 and 2000 in South America countries. They inferred from the results that the two approaches are consistent in their rankings and identification of the best and worst performers. They also observed that the efficiency scores were stable over time.[29] Haupt, Kinnunen and Pferffenger (2002) compared the network access prices of German electricity distributors and to identify reasons for differences beyond the decision framework of companies. In their analysis, they took cognisance of structural variables and regional specificities like settlement density and consumer structures. The main drawback of their study was that they used a single utility benchmarking approach that dealt exclusively with prices.

Whiteman (1999) evaluated the macroeconomic impact of reforms of the Australian electricity supply industry[30]. His analysis covered 3 industries namely electricity (41

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**28** They used two parametric models namely SFA and random effects model ad two non-parametric DEA approaches, one with variable returns to scale and the second one with constant returns to scale.

**29** They argued that though utility operators control most of the information required for regulatory purposes, and have little interest in volunteering their dissemination, Latin American's electricity sector could rely on an approach that utilises performance ranking, based on comparative efficiency to yield useful results. See details in Estache, A., Rossi, A. and Ruzzier, C (2002).

**30** He argued that many industries are characterised by multiple outputs and consequently the application of single output models may yield misleading results, particularly in relation to sign and significance of labour exponent of a conventional production function. See Whiteman, J. (1999) for detailed discussions of empirical results. He estimated 8 different multiple-output technical efficiency models for each of the electricity, gas and telecommunications models. See empirical details in Whiteman, J. (1999). "The Measurement of Efficiency, where there are multiple outputs".

suppliers for the period 1996-1997), gas (51 suppliers for the period 1992-1994) and telecommunication (31 suppliers for 1992). He used DEA, COLS and SFA to measure efficiency and then calculated potential increase in Total Factor Productivity (TFP). His empirical results seemed to suggest that the multiple models are more likely to yield coefficients of labour with the expected positive sign. Based on his empirical results, he also observed that the technical efficiency estimates from the deterministic and stochastic models were highly correlated. He therefore concluded that given the problem associated with estimating stochastic frontier models, the deterministic or COLS for estimating efficiency is to be preferred.

# CHAPTER 3 DATA COLLECTION: RESEARCH QUESTIONNAIRE

## 3.1 Introduction

The questionnaire design commenced with a meeting with project supervisors[31] at City University on February 1, 2005 to discuss details of the draft questionnaire. The amended version of the questionnaire and a project concept paper was forwarded to the Executive Council of the African Forum of Utility Regulators (AFUR) in South Africa in mid-February, 2005. With the permission of the Executive Council, a presentation on the objectives of the research project, as well as key aspects of the questionnaire was made to AFUR members, representatives of the World Bank and the National Association of Regulatory Utility Commissioners (NARUC), USA. The presentation was made at the Second Annual Conference of AFUR, held from March 14-16, 2005 in Kampala, Uganda. The questionnaire which is annexed as Appendix 1, was finally sent to the AFUR countries in April, 2005.

The next section provide details of the questionnaire and examine how the questions have been couched to elicit information on the output performance measures (i.e. the dependent variables) and the main independent variables for the econometric analysis. The questionnaire was structured to collect data and obtain relevant information, from the countries in the research sample, shown in Appendix 2, under the following six main headings:

i. Legal and Regulatory Framework
ii. Price Regulation
iii. Industry Structure
iv. Generation Sector
v. Transmission System
vi. Distribution System

## 3.2 Legal and Regulatory Framework

The scope of the legal framework that established the regulatory body is very crucial to the performance of the institution (Gutiérrez 2002, 2003; Brown et al. 2006; Kessides 2004). The stronger the legal mandate that established the institution, the more credible and sustainable would be the regulatory framework. Brown et al (2006) are therefore of the view that the regulatory agency should be created in a statute or primary law, that fully articulates its jurisdictional authority, powers, responsibilities and duties. In that regard, regulatory frameworks created

[31] Professor John Cubbin, Dr. Begona Garcia-Marinoso and Dr. Xeni Dassiou

by a country's legislature and embedded in a primary law are generally more credible and sustainable than those enacted by presidential decrees, since a new executive can easily repeal former decrees (Gutiérrez 1999, 2002).

The regulatory framework itself can be broken down along two dimensions namely, regulatory governance and content (Levy and Spiller 1994, 1996; Brown et al. 2006; Kessides 2004). Brown et al. (2006) identified the two important dimensions of regulation as regulatory governance and regulatory substance. They defined regulatory governance as the institutional and legal design of the regulatory system (i.e. the "how" of regulation), and referred to regulatory substance, as the actual decisions made by the regulatory agency (i.e. the "what" of regulation)[32].

The questionnaire has been designed to capture needed information on regulatory governance and regulatory content using Stern-Holder typology (1999). This approach will facilitate the construction of separate regulatory framework indices for the formal and informal aspects of regulation, for use in the econometric analysis. To elicit information on the formal aspects of regulation, questions such as when electricity law was passed, whether the regulatory agency was established by presidential decree and whether the regulatory functions are unambiguously spelt out in the primary law were asked.

Since the operational autonomy of a regulatory agency is driven largely by factors such as source of funding, the legal and technical expertise as well as the government's willingness to recognise the authority of the regulatory body (Brown et al. 2006; Kessides 2004; Au 2002), the questions were also formulated to capture responses from the countries on all these issues. Questions on the informal aspects relate to the existence of appeals mechanisms, the degree of consultation with stakeholders, transparency and consistency of regulatory decisions and ease of accessibility to key regulatory documents, such as rate-setting guidelines by stakeholders

The questionnaire also investigated the regulatory organisation with respect to regulatory capacity and expertise, an area which has persistently served as a barrier to the development of strong and credible regulatory agencies in Africa.

[32] For details see Brown et al (2006), "Handbook for Evaluating Infrastructure Regulatory Systems".

Details of the questionnaire on the legal and regulatory aspects, are annexed as Appendix 1A.

## 3.3 Industry Structure

When it comes to market structure, horizontal and vertical unbundling in most African countries have either slowed down considerably or stopped, such that no country is yet to establish a competitive wholesale electricity market[33] (Eberhard 2005). According to Eberhard (2005), the closest most countries have come to is limited to competition 'for' the market, through the issuance of competitive bids for new power projects, private concessions or management contracts. Issues relating to the market structures and the wholesale market designs in African countries, are being investigated as part of the study. Questions such as degree of unbundling between the generation and transmission or the level of vertical integration have been asked. This aspect of the questionnaire also elicit information on the level of privatisation or private sector participation (PSP) in generation and distribution sectors of each country's electricity supply industry (ESI).

Though complete retail competition[34] may not necessarily exist in most African countries (Bhagavan 1999), there is a possibility that 'partial' retail competition may be present in some countries. The questions therefore ascertain whether consumers are allowed to choose their own suppliers and what is the minimum consumption threshold required for consumers to do that. The structure of the questionnaire on industry structure is attached as Appendix 1C.

## 3.4 Generation Sector Data

Power utilities in most African and developing countries are supply constrained such that load generation is hampered by inability to expand the transmission and distribution systems to increase the number of connected customers (Karekezi et al. 2001; Bhagavan 1999; International Energy Agency 2002). Information and relevant data was requested on the generation segment of the Electricity Supply Industry

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**33** Denny and Dismukes (2002), define Wholesale Electricity Markets as bulk power markets where purchasers are not the ultimate end users of electricity. A wholesale power market transaction is therefore the one where a utility that is short on capacity purchases electricity from another utility in order to supply power to its own customers.

**34** Retail markets are also defined as the type of markets where customers are the ultimate end users of the electricity purchased. See Denny and Dismukes (2002) for further discussions on power markets.

(ESI) to cover installed generation capacity, net energy generated for the various generation sources namely thermal, hydro, nuclear and renewable energy technologies. This generation data is used to calculate plant capacity utilization rates.

The second set of questions asked for detailed information and data on ownership status and market shares between the public and private sectors. The information gathered can be used together with data on plant installed capacity, and to compile data for generation plant investment by the private and public sectors. The questionnaire is attached as Appendix 1D.

### 3.5 Transmission Sector Data

The transmission network is a natural monopoly and therefore considered a 'bottleneck' facility in the power sector, delivering essential services to the mass of the voting consumer population (Bhagavan 1999; Newbery 2006). It is not surprising that issues like access pricing principles, structure and regulation of the transmission business function, are considered as crucial to power sector reforms in all countries (Denny and Dismukes 2002).

One of the key requirements in the operation of the new power market is the provision of open-access to the transmission system which should be unbundled from generation (Newbery 2000, 2006)[35]. Unbundling will ensure that the monopoly network owner has no incentive to favour its own service provider (Newbery 2006) over network usage. Newbery (2001) argues that increased competitive pressure in generation is expected to reduce cost, but this will require unbundling transmission from generation. He was of the opinion that whether these gains would be passed-through to consumers would depend on the intensity of competition and existence of open-access transmission network.

The regulatory goal of the separation is to minimize horizontal and vertical market of incumbent utilities[36] (Denny and Dismukes 2002; Bacon 2001), and allow

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**35** According to Denny and Dismukes (2002), the unbundling can be categorised into functional and physical unbundling. Functional unbundling requires the utility to establish functionally separate entities, while physical unbundling requires utilities to sell off or divest themselves of certain assets.

**36** If left unchecked, the market power could skew market outcomes in favour of the incumbent utility and significantly reduce opportunities for societal gains from competition. For more details see Denny, F. and Dismukes, D. (2002), "Power System Operations and Electricity Markets", CRC Press.

competitive pressure to be put on the generation sector, while restricting cross-subsidies from the competitive sector to domestic consumers (Newbery 2006).

Bacon (2001) cautions that in many African countries, the total demand for power is extremely small, consumers are entirely dispersed, and this can make unbundling and competition ‘in’ the market difficult[37].The transmission network is considered the core of power sector reforms since it is the transmission operator or the Independent System Operator (ISO), which monitors and controls the transmission grid in real time, manage network congestion, by taking over the operational control of all power flows and transactions (Denny and Dismukes 2002).

The questions to the various countries were formulated taking cognisance of the afore-mentioned roles of the transmission business function. Some of the key questions relate to the technical aspects of the networks such as technical losses, system availability and transmission circuit kilometres. Responses to these questions would be used to determine the level of transmission system loss level and hence investment over the years, as well as the impact on the overall technical performance of the network system.

The questions have also been designed to gather information on the operational efficiency of the transmission organisation. Details of questionnaire on the transmission system can be found in Appendix 1E.

## 3.6 Distribution Sector Data

In African countries, most of the distribution companies perform the retail functions which comprise metering and billing, and therefore most of these state-owned companies are confronted with wide-spread theft of electricity (International Energy Agency 2002). This has resulted in high commercial or non-technical losses and low revenue collection rates which tend to undermine the financial viability of the distribution companies (Bhagavan 1999; Karekezi et al. 2001; Karekezi and Mutiso 1998).

[37] Bacon (2001) argues that the major gains in the future are likely to come from those steps, which introduce, which introduce the profit motive, rather than those designed to produce competition ‘in’ the market.

These problems are exacerbated by political interference and weak accountability such that the state-owned utility companies in Africa have little incentive to improve their performance (Karekezi and Mutiso 1998; ESMAP 1996). Private investors are reluctant to commit expensive capital investment, unless they can be assured hat they will subsequently be permitted to charge remunerative prices (Newbery 2006). Reducing technical and commercial losses can go a long way to enhance the financial position of the distribution utilities (Karekezi et al. 2001) and avoid the shock created by large increases in electricity tariffs. Newbery (2006) is of the view that the only solution under private ownership is regulation, but poorly designed or incomplete regulation is likely to lead to sub-optimal outcomes.

The questionnaire for the distribution sector has been designed to capture the above concerns and the set of questions include among others, those relating to industry structure, distribution system access and regulation. The second set of questions cover operational performance like staff strength, number of connected customers, total operating and maintenance expenses. The third group of questions request data and information on the following areas:

- distribution system technical loss and commercial loss levels
- revenue collection rate,

Details of questions on the distribution segment of the ESI are annexed as Appendix 1F.

# CHAPTER 4 REGULATORY FRAMEWORK INDEX

## 4.1 Introduction

This chapter focuses on the construction of regulatory index by using an empirical technique, Principal Component Analysis (PCA), and decomposing the index, into *formal and formal regulatory indices,* for use as independent variables in the econometric analysis. The method of PCA is used to produce a small number of variables (Hsieh 2004; Everitt and Dunn 1991; Hotelling 1933), that are uncorrelated and which account for most of the variation in the original data set (Hatcher and Stepanski 1994; Suhr 2003; Hsieh 2004). PCA operates on the principle that when different characteristics are observed about a set of events, the characteristic with the higher variation tend to explain a greater proportion of the event, compared to a variable which displays a lower variation (Andres et al. 2008).

According to Brown et al. (2006), any regulatory system can be defined along two important dimensions namely, regulatory governance and regulatory substance. Regulatory governance or the formal aspects describe the institutional and legal characteristics, while the informal attributes or regulatory substance, describe the actual regulatory practices and quality of regulation, along with the rationale for regulatory decisions (Brown et al. 2006)[38]. It has however been observed that most previous empirical studies tend to focus on the institutional and legal aspects (i.e. the formal aspects of regulation), hence the attempt to decompose the regulatory index into formal and informal regulatory indices.

This first part of this chapter identifies the key characteristics of 'best practice' utility regulation, to provide the basis for the construction of the formal and informal regulatory indices. The chapter ends by using the method of principal component analysis, to construct the indices over the study period to be used as part of the independent variables in the econometric estimation. This approach is in tandem with the observation by Brown et al. (2006) when they stated that "any evaluation of the regulatory effectiveness must examine the entire regulatory system and not just the characteristics and actions of the formally designated regulatory entity"[39].

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**38** Detailed description on methods of evaluation of regulatory effectiveness can be found in Brown, C., Stern, J., Tenenbaum, B. and Gencer, D., (2006). "Handbook for Evaluating Infrastructure Regulatory Systems", the World Bank, Washington D.C., USA.

**39** Brown et al. (2006) noted if such an approach is not adopted, this can lead to flawed conclusions being drawn because the new agency may possess only limited decision making authority, both in law

## 4.2 Characteristics of Best Practice Utility Regulation

The last decade has seen a gradual restructuring of the electricity sector in most Africa countries to permit private sector participation, and progressively open the generation sector to competition. Since electricity is essential to the life of the citizens of a country, the health of the economy and also affect the international competitiveness of its industries (Office of Water Regulation, Australia 1999), most governments have embraced the idea of establishing regulatory agencies. Apart from the significant public interest dimensions, regulation is also necessary to mimic or be a surrogate for competition in the market (Au 2002).

The regulatory body has a very critical role to play to ensure a successful implementation of the power sector reforms, since its decisions are bound to have far reaching implications for consumers, producers and the entire economy. An effective and efficient regulatory framework will require a regulator to carry out its functions in a fair manner and be seen to be doing so, in order to gain the trust, credibility and confidence from all stakeholders and market participants (Office of Water Regulation, Australia 1999; Au 2002).

Kennedy (2003) cautions that in discussing regulatory frameworks, it is advisable to follow the distinction by Levy and Spiller (1996), by differentiating between regulatory governance and regulatory content. Kennedy (2003) is of the view that regulatory governance, which basically refers to the institutional context for regulation, is key to monitoring regulatory or political risk. He defines regulatory content to cover issues relating to regulatory rules, tariff methodology etc.

Many African countries that have established regulatory bodies face severe challenges such as lack of professional expertise, inadequate financial resources and obtaining the necessary statutory authority (Kessides 2004). In that regard, one requires both the legal aspects of regulation and actual regulatory practice, as the key determining factors of how an effective regulatory environment can support reforms, promote efficiency and fulfil the desired social objectives (Smith 1997; Stern and Holder 1999; Brown et al. 2006). According to Stern (2000), effective regulation requires more than the formal attributes such as the enactment of

and in practice. Detailed discussions are available in Brown A., Stern, J., Tenenbaum, B., and Gencer, D. (2006), “Handbook for Evaluating Infrastructure Regulatory Systems”, World Bank, Washington D.C., USA.

electricity sector law, clarity of roles and objectives. This implies that a regulatory framework will not operate effectively unless in addition to the formal attributes, the informal aspects of regulation namely participation, transparency and predictability or consistency in decision making are given the necessary attention.

#### 4.2.1 Formal Attributes of Regulation.

Formal aspects of effective regulation relate to matters of institutional design and the legal framework for establishing the regulatory agency. These attributes cover issues relating to clarity of the roles of the new agency, regulatory independence, the legal framework which established the regulatory body and accountability. These sub-components are now discussed below:

##### 4.2.1.1 Clarity of roles and avoidance of conflicts of interest.

A good regulatory model is one which unambiguously spells out the functions of the regulator in the primary law or any other relevant document, and removes any possible sources of confusion between the regulator, the sector ministry or any other agency (Bertolini 2006; Brown et al. 2006). Regulation is made more effective through the separation of the role of the policy/regulation maker (i.e. the government), the policy/regulation implementer (i.e. the regulator), the utility operators or other regulatory agencies, such as the environmental agency (Au 2002). To minimise policy confusion and overlapping or contradictory responsibilities, the functions of the regulatory agency should as far possible, be kept separate from policy functions (Bertolini 2006).

##### 4.2.1.2 Independence

Regulatory independence can be defined as “independence of control by the governor and the legislature, independence of control by utility companies and independence in the sense of integrity and impartiality” (Fesler, quoted in Mitnic 1980, Pg. 69). This definition emphasises the independence from government, from the regulated industry, thus ruling out any traditional corporatist arrangement (Johannsen 2003). Regulatory independence thus refers to a situation where the regulator’s decisions are free from undue influences, which could compromise regulatory outcomes (Office of Water Regulation, Australia 1999; Brown et al. 2006). According to Au (2002) Regulatory independence can be analyzed from the following two perspectives:

(a) Independence from the Executive or any arm of government.

(b) Independence from market players, such as industry consumers and the regulated industry.

**(a) Independence from the Executive arm of government:**

Regulatory Agencies must be objective, apolitical enforcers of policies in controlling statutes (Kessides 2004). Eberhard (2005) identified at least three dimensions of regulatory independence as follows:

i. decision making independence
ii. institutional and management independence
iii. financial independence

Regulatory independence can be realized by clearly spelling out the functions of the regulator in the primary law which established the regulatory agency. A clear separation of functions will ensure that independent regulators hold exclusive decision-making powers to ensure that the decisions relating to electricity tariff levels or rates of return earned by operators, are not compromised by government pressure (Kessides 2004; Demarigny 1996). In addition, the independent regulator should be able to effectively combine the functions of rule making, rule application and litigation (Demarigny 1996)

The list of regulatory bodies in Africa and their mode of creation, as well as the year of legal establishment is presented in table 4.1 below:

**Table 4.1 Regulatory Agencies and mode of creation**

| **Country** | **Name of regulatory Body** | **Created by:** | **Year of Legal Establishment** |
|---|---|---|---|
| Algeria | Electricity and Gas Regulatory Commission | Electricity Act 2002, | 2005 |
| Cameroon | Electricity Regulatory Agency | Electricity Sector Law No. 98/022 | 1998 |
| Ethiopia | Ethiopian Regulatory Agency | Electricity Proclamation No. 86/1997. | 1997 |
| Gambia | Public Utilities Regulatory Authority | Public Utilities Regulatory Authority Act, 2001. | 2001 |
| Ghana | Public Utilities | Public Utilities | 1997 |

| | | | |
|---|---|---|---|
| | Regulatory Commission | Regulatory Commission Act, Act 538 | |
| Ghana | Energy Commission | Energy Commission Act, Act 541 | 1997 |
| Kenya | Kenya Regulatory Board | Electricity Power Act No. 11 of 1997 | 1997 |
| Malawi | National Electricity Council | Electricity Act of 1998 | 1998 |
| Mali | Water and Electricity Regulation Commission | Parliamentary Law, Order No. 00019/RM | 2000 |
| Namibia | Electricity Control Board | Electricity Act, 2000 | 2000 |
| Nigeria | Nigerian Electricity Regulatory Commission | Electricity Power Sector Law, 2005 | 2005 |
| Rwanda | Rwandan Regulatory Agency | Energy Reform Law 18/89 | 1999 |
| Senegal | Electricity Sector Regulatory Commission | Parliamentary Law No. 98-06 | 1998 |
| South Africa | National Electricity Regulator, later replaced by the National Energy Regulator | Electricity Act of 1994, amended by the Act of 2004 | National Electricity Regulator was established in 1995, and replaced by the National Energy Regulator[40] in 2005. |
| Uganda | Electricity Regulatory Authority | Electricity Act of 1999 | 1999 |
| Zambia | Energy Regulatory Board | Energy Regulation Act No. 16 | 1995 |
| Zimbabwe | Electricity Regulatory Commission | Electricity Act 2002 | 2003 |

[40] The National Energy Regulator is a multi-sector body with responsibilities for electricity, natural gas and piped petroleum products.

It emerged from the country survey that in Africa, government or ministerial interference seemed to have hampered the smooth performance of the regulator's function. This observation seems to have been corroborated by Kessides (2004) who noted that political interference has undermined regulatory independence in many developing countries, because governments or the line Ministries are reluctant to leave important regulatory functions to independent agencies.

In June, 2001 for instance, the Ugandan Electricity Regulatory Authority's decision to increase rates by almost 158% was brought to the floor of Parliament to be debated after which it was decided that the rates should be reduced. In Ethiopia, the regulator's tariff setting responsibility is limited to that of an advisory role to the Minister, who ultimately determines the tariffs, thus making one to question the operational independence of the regulator.

In Kenya, though the regulatory agency was established under legislation, a second statute, the State Corporation Act also covers the regulatory body, thus placing the regulator under the sector Ministry. In 2001, the entire Board of the regulatory agency was replaced. When it comes to issuing of licenses for operators, the regulatory agency's function is limited to that of an advisory body. The sector Minister effectively takes decisions on matters relating to granting, suspension and revocation of licenses.

An arms-length relationship with the government is expected to enhance the credibility and reliability of regulatory decisions, and assure stakeholders that decisions are based on clear criteria objectively applied, and that the regulator can be held accountable and answerable for all its decisions[41]. Kessides (2004) however cautions that in practice, compromise is needed to ensure that regulators are both independent and responsive to an elected administrator's policy goals. This assertion appears to be supported by Au (2002) who noted that the relationship between the regulator and the government must reflect the legal and

[41] Au (2002) argues that where the government owns or has majority shares in the equity interest in the main utility companies, independence from the government is very crucial. This will ensure that regulatory decisions are not influenced by considerations relating to the interest in the revenue or profitability of the utility companies. Even if the government does not have any equity stake in the main companies, independence is still required to insulate the regulator from political pressure. See Au, M. (2002), "Country Experience with Competition: Enhancing Transparency and Credibility of the Regulatory Process", Office of Telecommunications Authority, Hong Kong.

political systems of the country, and also reflect the status of development of the utility market in that country.

**(b) Independence from Market Participants:**

Independence from market participants will ensure that decisions, procedures and guidelines adopted by the regulator are impartial. A regulator which is independent from market participants is more likely to take consistent, transparent and predictable decisions. These attributes help to build the trust and confidence in the regulatory process (Office of Water Regulation, Australia 1999). Independence from market participants will be bolstered if the regulator possesses the needed technical, economic and legal expertise for decision making without undue influence from, or reliance on market participants (Au 2002; Office of Water Regulation, Australia 1999).

Regulatory Independence, whether from political interference or market participants, is easier to achieve if the regulator derives its source of funding from levies, license fees or regulatory charges imposed on the regulated industry, instead of relying on government budgetary support (Bertolini 2006; Kessides 2004; Smith 1997; Au 2002)[42]. The issue of secured source of funding implies that the regulator does not have to compete with other government departments for funds from the central budget. This will give the regulator the needed flexibility to react faster to deploy the needed resources to deal with industry problems, and meet other demands in a timely manner (Au 2002).

#### 4.2.1.3 Accountability.

There is no doubt that regulators are generally vested with such extensive powers, and therefore a best practice regulatory model, according to Kessides (2004) and Bertolini (2006), should ensure that:

- the necessary mechanisms are in place to guarantee that regulators behave in accordance with the legal mandate which established the agency
- regulators are held accountable and answerable for their decisions.

[42] Bertolini (2006) however cautions that independence should be balanced by accountability. Legal and regulatory instruments should permit stakeholders to challenge regulators' decisions and seek redress.

The Regulator's independence should therefore be reconciled with its accountability (Kessides 2004)[43]. There should be adequate checks and balances to prevent any abuse of the extensive powers vested in the regulator, by ensuring that the regulator is fully accountable for its decisions (Au 2002). The regulatory framework is made more accountable through the establishment of well-defined decision making processes, discussing draft regulatory decisions and providing the rationale to support decisions. Publication of consultative papers and inviting comments prior to any major decision will also go a long way to enhance accountability[44]. The existence of an appeal mechanism and adherence to the principles of procedural fairness will also give confidence to all market players (Office of Water Regulation, Australia 1999).

Since the regulator's decisions will affect the investment decisions of operators, investors will be more confident if there is an appeal mechanism for resolving disputes between the regulator and the operators. This implies that the regulator should be allowed bounded and accountable discretion through supervision from the judicial system, the legislature or through an ombudsman, for dispute resolution in the performance of its functions (Au 2002).

Based on the results of the country survey conducted as part of this study, it emerged that the dispute resolution mechanisms in most African countries work through either a Ministerial appeal system or normal courts. For example in Cameroon, though there is a competition commission, the Ministry of Energy is required to handle all disputes between the regulator and operators. The regulator is not required under the Act which established the agency, to submit annual reports to Parliament or any other body.

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**43** According to Kessides 2004, a regulator has considerable leeway for opportunism and therefore checks and balances are required to ensure that the regulator do not behave capricious, is not corrupt or grossly inefficient. He however admitted that it is difficult to strike a proper balance between independence and accountability in practice, though certain measure can help. See detailed discussions in Kessides (20064).

**44** As noted by Au (2002), by consulting with stakeholders, the regulator is seen to have addressed all relevant concerns. Although in practice it is not possible to satisfy all wishes because of divergent views from stakeholders, the consultation process will enable the regulator to make better and more informed decisions.

In Namibia, an appeal against a decision is made directly to the Minister within 30 days of the regulator's decision. The regulator is required to submit its annual report to the sector Minister, within six months after the end of the year. In Ghana, South Africa and Ethiopia, the regulators are required under their respective Acts which established them, to submit annual reports directly to Parliament, while any appeals against their decisions are routed through the normal court system.

### 4.2.2 Informal Attributes of Regulation.

The informal attributes of regulation refer to *actual actions or decisions* of regulators which affect the performance of the regulated industry and the overall sector (Brown et al. 2006). Informal attributes thus refer to the *practical operation* of regulatory practices and process (Stern and Cubbin 2005). Though the formal requirements are essential for effective regulation, they are not sufficient (Kessides 2004), hence the need for an effective regulatory agency to also possess good informal regulatory characteristics. The key components of informal aspects of regulation are discussed below.

#### 4.2.2.1 Transparency and Openness

The Regulator can gain the needed stakeholders' confidence and acceptance if it maintains a high degree of openness and transparency in its decision-making process through dissemination of information (Stern 1997), adopting a consultative approach to decision making and providing rationales for decisions made (Office of Water Regulation, Australia 1999)[45]. Transparency will enable stakeholders have a better understanding of the regulator's decisions, and enhance the acceptance of that decision. This will greatly catalyse investment and avoid costly, time-consuming regulatory disputes (Kessides 2004). By making the regulatory process less opaque, the integrity of the decision making process is enhanced and fewer appeals and complaints are likely to come from the operators, thus creating a less adversarial climate for regulation.

Some of the tried and tested approaches for enhancing the openness and transparency in the regulatory design according to Brown et al. (2006), Bertolini (2006) and Au (2002) are as follows:

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**45** As was also noted by Au (2002), the media has an important part to play to promote openness and transparency through press releases to accompany major regulatory decisions and explain salient points in the layman's language.

(i) Conducting public hearing prior to making major decisions[46]

(ii) Invitation to meetings, seminars and conferences to explain the work and processes of the regulatory framework.

(iii) Publication of reasons behind decisions, which can be done effectively on the regulators website. All other information which may be useful to the industry, subject to the rule of confidentiality, can be put on the website.

(iv) Making major regulatory documents such as technical reports, rate-setting guidelines, and market statistics available to stakeholders via the website.

To promote transparency in the regulatory framework, the regulator must take cognizance of the fact that some information provided by the regulated industry are commercially sensitive (Office of Water Regulation, Australia, 1999) and a full disclosure to the public may adversely affect the interest of the operator. To give comfort to operators and to make the regulatory process very credible, the rules regarding which information is classified as confidential should be identified early, as part of the regulatory decision process (Office of Water Regulation, Australia 1999). It is important that in dealing with the issue of confidentiality of information, the regulator must strike a good balance between the interests of the operator against the public interest to disclose, in order not to create an opaque regulatory environment (Au 2002).

#### 4.2.2.2 Participation

A regulatory process is said to be participatory if stakeholders are given the opportunity to contribute effectively to enhance the credibility and legitimacy of the process (Au 2002). Participation may take the form of a formal consultation with stakeholders to build the latter's commitment to the process. It also provides a conduit for stakeholders to discuss the impact of regulation, make constructive criticisms and suggest alternatives for improvement (Bertolini 2006). Effective participation offers opportunity to all stakeholders to contribute to the decision

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[46] Brown et al (2006) cautioned that no major decision should be made without being set down in a publicly available written document. They suggested the following as some of the measures which can be adopted among others:

i. providing a clear statement of the decision

ii. providing a summary of statement of views offered by stakeholders

iii. providing a full disclosure of underlying rationale for decisions making process so that the quality of regulation is maximized by the regulatory. It also enhances the level of communication between the regulator and other players in the market (Office of Water Regulation, Australia, 1999).

Effective participation by stakeholders reduces the degree of information asymmetry between the regulator and stakeholders (Au 2002), by enabling the latter to have a better understanding of regulatory objectives and decisions. It also reinforces openness and transparency, which is achieved by making key regulatory documents available to stakeholders, and explaining the rationale behind major regulatory decisions.

#### 4.2.2.3 Consistency and Predictability

Regulatory decisions should as far as possible, be consistent with previous decisions or determinants in the past (Brown et al. 2006). The principles of consistency and predictability will assure investors that there will not be unexpected changes to the regulatory environment and this will enable them to make future investment decisions which are long-term in nature with a high degree of certainty (Office of Water Regulation, Australia 1999). Lack of predictability and consistency in the regulator's decision will result in lack of confidence in the regulatory process by stakeholders, and undermine the size, scope and quality of infrastructure and related investment (Kessides 2004).

To achieve consistency and predictability in decisions, the regulator must note that the practice of utility regulation is one of the most dynamic disciplines to have emerged and it is imperative that as circumstances change over time, the regulator must be flexible and develop new ways of solving emerging regulatory challenges. Bertolini (2006) notes that in practice, the regulator should ensure some trade-off between predictability and flexibility, and cautions that this trade-off should be handled with care. This flexibility to achieve evolutionary change in regulatory approaches should be orderly and must take cognizance of the local institutional endowment and local market conditions (Office of Water Regulation, Australia, 1999).

## 4.3 Construction of Regulatory Framework Index

Though Gutiérrez (2002) made an attempt to measure the regulatory trend in the telecommunications sector, by constructing an index of regulatory framework for 22 Latin America and Caribbean countries for the period 1980-1997, similar empirical work is yet to be carried out exclusively for African countries. The focus of this section of the study, is therefore to examine the trend in Africa's electricity sector regulatory framework, by constructing separate formal and informal regulatory indices for the period 1988-2005. The derived indices would then be used as part of the independent variables, in panel data econometric analysis.

### 4.3.1 Previous Work

According to the economics literature, one of the first attempts to construct an index of regulatory framework was by Gutiérrez and Berg (1999). They used the following factors from a paper by Galal and Nauriyal (1995):

- (i) Regulatory neutrality and autonomy
- (i) Agency enforcement power
- (ii) Conflict resolution mechanism.

Gutiérrez and Berg (1999) adopted an approach which involved the construction of a dichotomous index where a value of one was attributed to a regulatory agency possessing at least two of the afore-mentioned factors and zero otherwise. There was no doubt that the construction of the index was a major step which later proved useful in econometric analysis. According to Gutiérrez (2002), the index by Gutierrez and Berg (1999) however suffered from the following shortcomings:

- (i) Data was based on secondary sources and it involved a high degree of subjectivity.
- (ii) There was ambiguity in result interpretation. For instance an attainment of a value of one by a country may erroneously be interpreted to mean a country has achieved a complete regulatory development.

In an attempt to ensure the robustness of the regulatory index for econometric analysis, Gutiérrez (2002) later made an attempt to construct an 8-element index, each with a weight of 12.5%, for 22 Latin American and Caribbean countries. The major breakthrough by Gutiérrez (2002) was that, the index was dated or time-dimensioned. Table 4.2 summarizes the approach used by Gutiérrez (2002).

**Table 4.2 Regulatory Index Methodology by Luis Gutiérrez (2002)**

| Attribute of Regulation | Factors or Elements | Weight (%) |
|---|---|---|
| **1. Legal Mandate** | (i) Regulatory established by Law or Presidential Decree | 12.5 |
| **2. Separation** | (ii) Separation of regulatory and Operating activities | 12.5 |
| **3. Clarity of roles and objectives** | (iii) Ability to impose fines | 12.5 |
| | (iv) Ability to set tariffs | 12.5 |
| **4. Independence** | (v) Financial/Budgetary Independence | 12.5 |
| | (vi) No free removal of commissioners | 12.5 |
| **5. Accountability** | (vii) Existence of Dispute Resolution Mechanism | 12.5 |
| **6.Transparency/Participation** | (viii) Existence of hearings for setting tariffs | 12.5 |
| | **8-Elements** | **100.0** |

Cubbin and Stern (2005) also used a regulatory index as a key explanatory variable to carry out econometric analysis on the electricity sector. In constructing their index they used four factors shown in the table below.

**Table 4.3 Regulatory Index Methodology: Cubbin and Stern approach (2005)**

| Attribute of Regulation | Factors of Elements | Weight |
|---|---|---|
| **1. Legal Mandate** | (i) whether the country has an electricity or (energy) regulator law | 1.00 |
| **2. Type of Regulator** | (ii) Whether the country has an autonomous or a ministry regulator | 1.00 |
| **3. Independence** | (iii) Whether funding is derived from licence fees (or equivalent) or out of government budget | 1.00 |
| **4. Independence (Staff Salary)** | (iv) Whether staff is confined to civil service pay or staff pay is based on appropriate skills | 1.00 |
| | **4-Elements** | **4.00** |

Gual and Trillas (2004 and 2006), also measured the regulatory independence in the telecommunication sector for 37 countries, from North and South America, Europe and Africa, for one year (i.e. 1998), by creating two principal indices. The first index was for liberalisation policies, while the second index comprised eleven elements. Edwards and Waverman (2006) constructed a 13 element index of regulatory independence for 15 European Union countries. Zhang et al. (2005) also constructed a 4-element regulatory governance index which measured the formal attributes of regulation.

Muntoya and Trillas (2006) also measured regulatory independence of 23 Latin American countries in the telecommunications sector, for the period 1990-2004. Muntoya and Trillas (2006) constructed 3 separate indices namely IR1 using Gual and Trillas (2004 and 2006), IR2 using Edwards and Waverman (2006)[47], and IR3 using Gutiérrez (2002).[48]

Though the above attempts to construct an index of regulatory independence is expected to make a significant contribution to the literature, the issue raised by Cubbin and Stern (2005), and Stern and Cubbin (2005), concerning the non-inclusion of informal attributes of regulation, appeared not to be fully addressed. Cubbin and Stern (2005) argued that the use of a regulatory index in econometric analysis, to take account of the informal aspects of regulation, will go a long way to enhance the robustness of the estimates. They also cautioned that the absence of data on the informal aspects of regulation due probably to data unavailability, could lead to the problem of errors-in-variables in econometric analysis. They therefore recommended that researchers must in future, endeavour to include data on the informal characteristics.

Cubbin and Stern (2005) also raised issues on the use of the equal weights on each of the factors or elements. To address this problem in the present study, Principal Component Analysis (PCA) has been used to determine the weights used for calculating the formal and informal regulatory indices.

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[47] Edwards and Waverman (2006) used 13 components to construct the index, while Muntoya and Trillas (2006) used 11 components. The difference was due to lack of information on interconnection and agency budgets.

[48] Muntoya and Trillas (2006) noted that all the 3 different approaches provide approximately the same conclusions that regulatory independence, at least de jure, appears to have a positive impact on network penetration.

## 4.4 Proposed Approach

### 4.4.1 Formal Regulatory Index.

The construction of the formal regulatory index is based on the following three-stage process:

(i) Identification of key factors for measuring each attribute of regulation

(ii) Assigning 0/1 dummy variable for each factor.

(iii) Determination of appropriate weights for each factor.

#### 4.4.1.1 Identification of Factors and assigning dummy variables

The formal regulatory index is based on seven factors which describe the four key attributes of regulation, by using Stern-Holder (1999) classification. The value for each factor is a dichotomous value of either 0 or 1, based on the criteria established in table 4.4 below, where the switch from 0 to 1 is dated and therefore a function of time. Table 4.4 summaries the approach adopted for the first two stages of the formal index construction process (i.e. identification of key factors, as well as the method adopted to assign 0/1 dummy value).

**Table 4.4 Formal regulatory factors: Assigning dummy values**

| Formal Attributes | Factors | Yes | No |
|---|---|---|---|
| **1. Legal Mandate** | (i) Whether country has energy/electricity sector law.<br>(ii) Regulatory Body established by Legislation or Decree | 1<br>1 | 0<br>0 |
| **2. Clarity of Roles and objectives and avoidance of conflict of interest** | (iii) Regulatory functions clearly spelt out in primary legislation or in any relevant document? | 1 | 0 |
| **3. Independence** | (iv) Financial/Budgetary Independence<br>(v) Whether the country has an autonomous or a Ministry regulator[49] | 1<br>1 = Autonomous | 0<br>0 = Ministry |

[49] One important measure of a regulator's independence is whether the regulator has final decision-making on tariffs. Ministry type regulators are normally accountable to the sector Ministry and therefore only play an advisory role by recommending tariffs for consideration to the Minister, who determines the final tariffs. It can be inferred that factor (v) in table 4.4 also measures the final-decision making authority of the regulator.

| | | | |
|---|---|---|---|
| **4. Accountability** | (vi) Existence of appeals mechanism for challenging regulatory decisions<br>(vii) Submission of Annual Report to Parliament or any other body. | 1<br><br><br>1 | 0<br><br><br>0 |
| | **TOTAL ELEMENTS: 7** | | |

**Source: Author's construction**

#### 4.4.1.2 Apportioning Weights: Principal Component Analysis

The problem of determining the weight for each factor is resolved by using a multivariate statistical technique called *Principal Component Analysis (PCA).* Principal Component Analysis is basically a variable reduction technique, which is used to reduce the observed variables which may be correlated with one another and are likely to be redundant, into a smaller number of principal components, *which account for most of the variance in the observed variables[50].* The details of steps used in conducting the PCA for the regulatory framework index calculation are annexed as Appendix 11.

In Principal Component Analysis (PCA), the number of components extracted equals to the number of observed variables, with the first principal component accounting for most of the variance in the identified data. The second component identified, accounts for the second largest amount of variance in the data and is uncorrelated with the first principal component and so on. The components which account for maximal variance are retained for data analysis, while the other components which account for insignificant amount of variance are not retained (Hotelling 1993; Everitt and Dunn 1991; Hsieh 2004; Suhr 2003).

The issue of determining the weights to be assigned to each factor is determined by the objective of maximising the variation in the linear composite of the variables. It is possible to determine the weights to be assigned from the magnitude of eigenvectors[51] associated to individual variables (Hotelling 1933). A key underlying

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**50** Variables are redundant because they are correlated with one another and possibly measuring the same construct.

**51** The eigenvectors are the weights in a linear transformation when calculating the principal component scores, while the eigenvalues indicate the amount of variance explained by each principal base to Principal Component Analysis[52] is that the chosen variables can be transformed into linear combinations (Suhr 2003)[53] of optimally weighted[54] average variables, which are unrelated and orthogonal (Hatcher and Stepanski 1994; Suhr 2003). Since the first principal component, captures the majority of the variation in the attributes, and far more than the second or subsequent components, the *first principal component* is used to develop a composite index for the regulatory index for each country. The regulatory index for each country is thus derived from a linear combination of the observed variables, weighted by the eigenvectors as follows:

$RIndex = B_{n1} X_1 + B_{n2} X_2 + B_{n3} X_3$ +--------------------------+ $B_n X_n$

where:

RIndex = Regulatory Index (i.e. formal or informal)

$X_1, X_2$, ----------$X_n$ = Matrix of scores

$B_{n1}, B_{n2}$, ------ $B_{ni}$ = Matrix of eigenvectors (i.e. weights).

After the eigenvectors for all the principal components are determined, the next critical issue is to decide which principal component's eigenvector should be used as the weights to calculate the index. This problem was resolved using the Kaiser Criterion (1960) which states that[55] principal components with eigenvalues greater than 1 should be retained. This means that each principal component will explain at least as much variance as 1 observed variable, and therefore accounts for a

component or each factor. For further detailed discussions, see Suhr (2003); Hsieh 2004; Pruzek 1988; Everitt and Dunn 1991.

**52** Although Factor Analysis and Principal Component Analysis often give similar results, the main practical difference between the two lies in the fact that if the number of factors is changed, all the loading in a factor analysis will change, while those from Principal Components do not. See Pruzek (1988) for further discussions.

**53** Linear combination implies that the scores on a component are created by adding together scores on the observed variables being analysed.

**54** Hatcher and Stepanski (1994) explain that the weights are created so as to satisfy a principle of least squares, similar (but not identical) to the principle of least squares used in multiple regressions. Optimal weights according to Hatcher and Stepanski (1999) means that no other set of weights could produce a set of components that are more successful in accounting for the maximal variance in the observed variables.

**55** Other tests used include the 'Scree Test' (Cattell 1996), Proportion of variance accounted for and the interpretability test (Hatcher and Stepanski 1994) meaningful amount of variance (Kaiser 1960; Hatcher and Stepanski 1994)[56]. The results of the eigenvalues are now reported in table 4.5 below.

**Table 4.5 Eigenvalues for all Principal Components: Formal Index**

| Principal Component | Eigenvalue | Variance Proportion (%) | Cumulative Proportion (%) |
|---|---|---|---|
| 1 | 5.5166 | 78.81 | 78.81 |
| 2 | 0.7983 | 11.40 | 90.21 |
| 3 | 0.2541 | 3.63 | 93.84 |
| 4 | 0.1792 | 2.56 | 96.40 |
| 5 | 0.1124 | 1.61 | 98.00 |
| 6 | 0.0962 | 1.37 | 99.38 |
| 7 | 0.0432 | 0.62 | 100.00 |

Based on the Kaiser test (1960), the eigenvectors for the first Principal Component, in table 4.6 below, are used as the weights for each of the 7 variables to determine the formal regulatory index.

**Table 4.6 Eigenvectors for first Principal Component: Formal Index**

| Variable | Eigenvector (i.e. weight) |
|---|---|
| 1. Existence of electricity sector law | 0.4088 |
| 2. Regulatory Body established by law | 0.4102 |
| 3. Regulatory functions clearly spelt out in primary legislation | 0.3911 |
| 4. Financial or Budgetary Independence | 0.3941 |
| 5. Whether the country has autonomous or Ministry Regulator | 0.3972 |
| 6. Existence of dispute resolution or appeals mechanism | 0.2338 |
| 7. Submission of annual reports to | 0.3793 |

[56] As noted by Stevens (1986), though the Kaiser criterion is very simple to use, it possess certain drawbacks such as the following:

i. can lead to retaining the wrong number of components
ii. can lead to retaining a certain number of components, when the actual difference in the eigenvalue of successive components is only trivial. See details in Stevens, J. (1986), "Applied Multivariate Statistics for the Social Sciences". Hillsdale, NJ, Lawrence Erlbaum Associates.

| | |
|---|---|
| parliament or any other body | |
| **TOTAL** | **2.6145** |

The results in table 4.6 clearly confirm the assertion by Cubbin and Stern (2005) that it may be incorrect to assign the same weight to each variable. Using the eigenvectors and the time-dimensioned dummy values, the formal regulatory index was calculated for each country, as the weighted average of the formal variables, listed in table 4.6 above. From table 4.6, it can be inferred that the maximum attainable value (i.e. if a country records 1 for all the factors, during the study period), is *2.6145.* The minimum value (i.e. if a country scores zero for all factors during the study period), is *0.0000.* A summary of the results for the formal regulatory index, is presented in table 4.7 below.

**Table 4.7 Results of Formal Regulatory Index.**

| Country | 1988-1997 Average | 1998-2005 Average | 1988-2005 Average |
|---|---|---|---|
| **Algeria** | 0.0000 | 0.1520 | 0.0676 |
| **Angola** | 0.0000 | 0.0000 | 0.0000 |
| **Botswana** | 0.0000 | 0.0000 | 0.0000 |
| **Cameroon** | 0.0000 | 2.2351 | 0.9934 |
| **Congo Rep (Brazzaville)** | 0.0000 | 0.0000 | 0.0000 |
| **DR of Congo (Kinshasa)** | 0.0000 | 0.0000 | 0.0000 |
| **Cote d'Ivoire** | 0.0000 | 2.1387 | 0.9506 |
| **Egypt** | 0.0000 | 0.0000 | 0.0000 |
| **Ethiopia** | 0.0803 | 1.8872 | 0.8834 |
| **Gabon** | 0.0000 | 0.0000 | 0.0000 |
| **Gambia** | 0.0000 | 1.3901 | 0.6178 |
| **Ghana** | 0.1607 | 1.9391 | 0.6178 |
| **Kenya** | 0.1447 | 2.5181 | 1.1995 |
| **Libya** | 0.0000 | 0.0000 | 0.0000 |
| **Malawi** | 0.0000 | 2.1361 | 0.9494 |
| **Mali** | 0.0000 | 1.4905 | 0.6624 |
| **Mozambique** | 0.0000 | 0.0000 | 0.0000 |
| **Namibia** | 0.0000 | 1.7147 | 0.7621 |
| **Nigeria** | 0.0000 | 0.2976 | 0.1323 |
| **Rwanda** | 0.0000 | 1.8866 | 0.8385 |

| | | | |
|---|---|---|---|
| **Senegal** | 0.0000 | 2.1841 | 0.9707 |
| **South Africa** | 0.6004 | 2.3806 | 1.3916 |
| **Sudan** | 0.0000 | 0.0000 | 0.0000 |
| **Tanzania** | 0.0000 | 0.0000 | 0.0000 |
| **Tunisia** | 0.0000 | 0.0000 | 0.0000 |
| **Uganda** | 0.0000 | 2.0908 | 0.9292 |
| **Zambia** | 0.5191 | 2.3806 | 1.3464 |
| **Zimbabwe** | 0.0000 | 0.9442 | 0.4196 |

**SOURCE: Author's construction**

From the above results, there is no doubt that African countries have generally experienced improvement in the formal regulatory framework to oversee the electricity sector. Since the Formal Regulatory Index (FRI) is a function of time and most of the regulatory bodies were legally established and stared operating between 1998 and 2000, this is reflected by the relatively lower FRI values for the period 1998-2005, compared to the period 1988-1997.

The results seem to identify the 'early starters' in the creation of regulatory frameworks as South Africa, Ghana, Kenya and Zambia. South Africa's National Electricity Regulator (NER) was established in 1995 under two laws namely, the Electricity Amendment Act 46 of 1994 and the Electricity Amendment Act 60 of 1995, as a successor to the Electricity Control Board, which was established by the Electricity Act of 1987 (Davidson and Mwakasonda 2003). In 2005, the NER metamorphosed into a multi-sector regulator, the National Energy Regulator, under Act No. 40, 2004 [57], with responsibility for electricity, natural gas and piped petroleum.

Zambia's regulatory agency was established by legislation through the Energy Regulation Act No. 16, while Ghana's electricity sector reforms commenced with the enactment of Acts 538 and 541 in 1997. Kenya's reform law was passed in 1997, and the regulatory body was established under section 119 of the Electricity Power Act.

It is worthy to note that among the North African countries that have passed an energy sector law, as at the end of 2005, it is only Algeria that has set a regulatory agency. The 'late comers' include countries such as Nigeria, Gambia and

[57] The National Regulator Act, 2004, received Presidential assent on April 6, 2005.

Zimbabwe, and therefore recorded a value of zero for the period 1988-1997, but showed positive values below or above one, for the period 1998-2005. Analysis of the country survey results show that with the exception of Ghana and Ethiopia where the regulatory bodies derive their source of funding from government central budget, all the other bodies possess independent sources of funding which are from licence fees or levies, paid by the electric utility providers.

#### 4.4.2 Informal Regulatory Index

##### 4.4.2.1 Identification of factors and assigning dummy variables.

The informal regulatory index was constructed by first determining the key informal attributes of regulation based on the Stern-Holder (1999) factor classification. From the three key informal attributes, five sub-factors were derived, and using the same approach adopted for the formal regulation index, the 0/1 dummy variables which are dated or time-dimensioned, are assigned to each factor. This approach is illustrated in table 4.8 below.

**Table 4.8 Informal regulatory factors: Assigning dummy values**

| **Informal Attributes** | **Factors** | **Yes** | **No** |
|---|---|---|---|
| 1.Transparency and Openness | (i) Publication of reasons behind major decisions and where?<br>(ii) Public accessibility to key regulatory documents and where? | 1<br><br>1 | 0<br><br>0 |
| 2. Participation | (iii) Existence of public hearings prior to tariff or other major regulatory decisions and indicate occasions used | 1 | 0 |
| 3.Consistency and Predictability | (iv) Difficult to change key regulatory documents such as licenses, Acts?<br>(v) Principles involved in tariff setting set out formally in a document such as rate-setting guidelines. | 1<br><br>1 | 0<br><br>0 |
| | **TOTAL ELEMENTS: 5** | | |

##### 4.4.2.2 Apportioning weights

The weights for each factor were determined using the method of Principal Component Analysis (PCA), the same approach used to calculate the formal regulatory index. The eigenvalues for the five principal components are shown in table 4.9 below.

**Table 4.9 Eigenvalues for all Principal Component: Informal Index**

| Principal Component | Eigenvalue | Variance Proportion ( % ) | Cumulative Proportion ( % ) |
|---|---|---|---|
| 1 | 3.0577 | 61.15 | 61.15 |
| 2 | 0.8203 | 16.41 | 77.56 |
| 3 | 06977 | 13.96 | 91.52 |
| 4 | 0.3056 | 6.11 | 97.63 |
| 5 | 0.1186 | 2.37 | 100.00 |

Using the Kaiser (1960) test, the following eigenvectors associated with the first Principal Component are used as weights for each of the 5 variables (see table 4.10 below).

**Table 4.10 Eigenvectors for first Principal Component: Informal Index**

| Variables | Eigenvector (i.e. weight) |
|---|---|
| 1. Publication of reasons behind major decisions in practice | 0.4930 |
| 2. Public accessibility to key regulatory documents | 0.5145 |
| 3. Existence of public hearings prior to major tariff decisions | 0.3049 |
| 4. Difficult to change key regulatory documents e.g. licenses, Acts etc. | 0.5248 |
| 5. Principles of rate-setting set out formally in a document such as rate-setting guidelines | 0.3518 |
| **TOTAL** | **2.1890** |

The next step was to use the eigenvectors and the time-dimensioned dummy variables to calculate the informal regulatory index for each of the countries. As explained in the case of the formal index, the informal index for each country was calculated as the weighted average of the factors listed in table 4.10 above. The maximum attainable value *(i.e. if a country scores 1 for all factors during the study period) is 2.1890).* The minimum value is 0.000, implying that a particular country has scored zero for all he factors, during the study period. The results for informal regulatory values are presented in table 4.11 below.

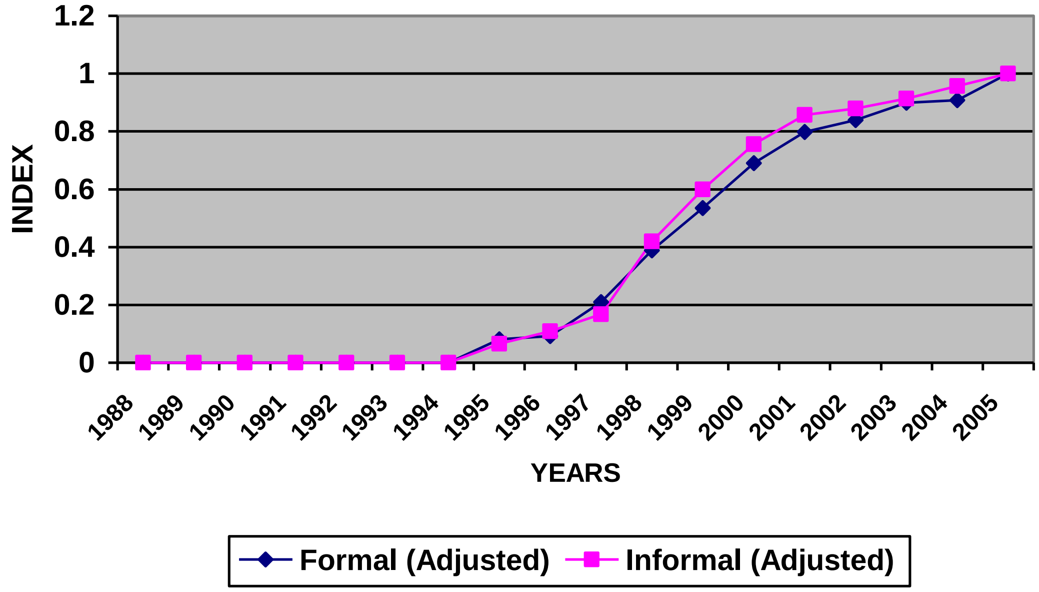
**Table 4.11 Results of Informal Regulatory Index.**

| Country | 1988-1997 Average | 1998-2005 Average | 1988-2005 Average |
|---|---|---|---|
| **Algeria** | 0.0000 | 0.0000 | 0.0000 |
| **Angola** | 0.0000 | 0.0000 | 0.0000 |
| **Cameroon** | 0.0525 | 1.4064 | 0.6542 |
| **Congo Rep (Brazzaville)** | 0.0000 | 0.0000 | 0.0000 |
| **DR of Congo (Kinshasa)** | 0.0000 | 0.0000 | 0.0000 |
| **Cote d'Ivoire** | 0.0000 | 2.1387 | 0.9506 |
| **Egypt** | 0.0000 | 0.0000 | 0.0000 |
| **Ethiopia** | 0.0877 | 1.3911 | 0.6670 |
| **Gabon** | 0.0000 | 0.0000 | 0.0000 |
| **Gambia** | 0.0000 | 0.1955 | 0.0869 |
| **Ghana** | 0.0000 | 1.8084 | 0.8037 |
| **Kenya** | 0.0000 | 1.7729 | 0.7880 |
| **Libya** | 0.0000 | 0.0000 | 0.0000 |
| **Malawi** | 0.0000 | 1.0393 | 0.4619 |
| **Mali** | 0.0000 | 0.6509 | 0.2893 |
| **Mozambique** | 0.0000 | 0.0000 | 0.0000 |
| **Namibia** | 0.0000 | 1.2432 | 0.5525 |
| **Nigeria** | 0.0000 | 0.0000 | 0.0000 |
| **Rwanda** | 0.0000 | 1.2765 | 0.5673 |
| **Senegal** | 0.0000 | 0.9750 | 0.4333 |
| **South Africa** | 0.2603 | 1.8841 | 0.9820 |
| **Sudan** | 0.0000 | 0.0000 | 0.0000 |
| **Tanzania** | 0.0000 | 0.0000 | 0.0000 |
| **Tunisia** | 0.0000 | 0.0000 | 0.0000 |
| **Uganda** | 0.0000 | 1.0849 | 0.4822 |
| **Zambia** | 0.4062 | 0.5615 | 0.9078 |
| **Zimbabwe** | 0.0000 | 0.5014 | 0.2228 |

**Source: Author's construction**

As shown in table 4.11 above and also illustrated in figure 4.1 below, the informal regulatory index which measures the actual practice of regulation has generally improved during the study period, but whether this trend is enough to catalyze investment in the electricity sector is an issue to be examined later, using econometrics. Figure 4.1 below summarizes the general trend of the regulatory framework in Africa. The period 1988-1994 (i.e. first 7 years of research study) can be described as the 'formative' period of the regulatory process in the electricity sector in Africa. The period 1995-2005 witnessed a significant transformation of the electricity sector regulatory framework in Africa as part of the Power Sector reforms.

**Figure 4.1 Average Trend of Regulatory Framework Index**




**Source: Author's construction**

It was observed that all the regulatory bodies were established by legislation as opposed to presidential decrees, and this makes it difficult for a new political leadership in the country to engage in arbitrary changes in policy. According to Gutiérrez (2002), regulatory frameworks created by the elected legislature body are stronger safeguards of stability than those formed by executive decrees. This implies that a regulatory framework established by decree can affect the credibility of the institution and hence have an adverse impact on investor confidence. Though the results showed a gradual improvement in the overall regulatory environment over the study period, it also emerged that question marks still hang around the regulatory independence of the tariff setting responsibilities of the regulators in some African countries[58].

[58] Wamukonya (2003) corroborates this observation when he noted that, when electricity tariff was increased by 158% on the average in 2001, consumer outrage forced the Ugandan President to intervene and seek tariff reductions. In 2002, the Court of Appeal in Kenya gave consumers to

# CHAPTER 5 DEFINITION OF ECONOMETRIC VARIABLES

This section of the thesis provides the definition and the basis for selecting the dependent and independent variables for the econometric analysis. Where possible, these definitions are supported by the appropriate mathematical formula.

## 5.1 Dependent Variables for Generation Sector

### 5.1.1 Per Capita Installed Generation Capacity

Increasing generation sector investment and capacity to reduce rampant load shedding and black-outs, are among the key objectives of most African governments, which have embarked on power sector reforms. To investigate what impact the reforms can have on generation capacity investment, per capita installed generation capacity has been used as a suitable proxy in the econometric modelling. The per capita installed generation capacity is expressed in kilowatt per person (i.e. kW per person) and calculated as follows:

*Total nameplate capacity of all installed power plants ÷ Total population.*

### 5.1.2 Generation Plant Utilization[59]

In a reformed power sector which is accompanied by effective regulation, competition and private sector participation in generation, it is expected that installed power plants would be utilised with minimum plant shut down periods. Plant utilization captures the extent of power plant capacity utilization and is therefore a good proxy for plant availability[60].

### 5.1.3 Per Capita Generation Energy Output

This is another important output indicator of power sector reforms which measures the performance of installed electric power plants. This output is expected to have wider socio-economic implications by impacting on a country's electrification level.

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challenge a 40% rise in electricity tariffs approved by the regulator. In 2008, the PURC (Ghana) gazetted the end-user tariff structure for residential lifeline consumers (0-50 KWh), but this was later amended by the government to 0-150 kWh.

[59] Mathematically, Load Factor is the same as the Capacity Factor, except that the former is used when referring to power users and consumers, while Capacity Factor is applied to power generating systems.

**[60]** Plant Availability (or Availability Factor) is the time period that the power plant can be operated, divided by the total period considered. Therefore, Plant Availability should either be equal to or greater than Capacity Factor.

Per capita generation plant output is expressed in Kilowatt Hours (kWh) per person and defined as:

*Total Energy Generation of a country ÷ Total population of a country*

## 5.2 Independent Variables

The selection of the explanatory variables draws from similar studies in the economics literature (Zhang et al. 2002; Wallsten 2001; Cubbin and Stern (2005); Gutiérrez (2003). The independent variables are now described below.

### 5.2.1 Regulatory Framework Indices

In an attempt to capture both the formal and informal attributes of regulation, the regulatory index has been decomposed into the formal and informal regulatory indices. The separation of the regulatory index into two indices, is an attempt to build on previous works (Gutiérrez and Berg 1999; Gutiérrez 2003; Cubbin and Stern 2005). Though details of the approach for constructing the indices are fully described in chapter 4 and previous paper[61], it is worth re-stating that by using the Stern-Holder (1999) typology, the formal index captures the following characteristics of regulation,

i. Existence of a legal mandate, particularly electricity sector law
ii. Clarity of roles and objectives, and avoidance of conflict of interest between the regulator, the sector ministry or other regulatory bodies
iii. Regulatory Independence
iv. Accountability on the part of the regulatory body, including the existence of an appeals mechanism.

The informal index was constructed from the following key factors which reflect the actual regulatory practice, and are also based on the following Stern-Holder (1999) classification:

i. Transparency and openness
ii. Ensuring effective stakeholder participation
iii. Ensuring consistency and predictability of regulatory decisions

[61] See Gboney, W. (2006) "Power Sector Reforms in Africa: Emerging Lessons in Regulation, Competition and Privatisation:

### 5.2.2 Privatisation Variables

The privatisation variables used for the study have been defined in line with those provided on the World Bank and PPIAF Data base (2008), on Private Sector Participation (PSP) options as follows:

**i. Management and Lease Contracts:**

Management and Lease contracts refer to a PSP option where the state-owned company transfers to a private company, the responsibility for management of the enterprise for a fixed period. The government or the public authority continue to remain the sole owner of the assets, and is also responsible for financing investments in infrastructure assets. While management contracts may be for duration of between 3 years to 5 years, lease contracts can be from 5 years to 10 years but the duration may be extended to 20 years.

**ii. Concession[62]**

Concession as a PSP option refers to a situation where the private operator (i.e. the concessionaire) is responsible for the operation, maintenance and management, as well as financing of capital investment for expansion of services. The assets remain the property of the government or the public authority, but are entrusted to the concessionaire for the duration of the contract. The assets must however revert to the government in the same condition at the end of the concession contract, which can be for a period of 25 or 30 years (World Bank and PPIAF Database 2008; Idelvovitch and Ringskog 1997).

**iii. Greenfield Projects[63]**

Greenfield Projects can either be a private or a joint venture public-private entity which builds and operates a new facility for a period specified in the contract. The project may at the end of the contract, return to the public sector.

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[62] The World Bank and PPIAF Database classifies concessions as: Rehabilitate Operate and Transfer (ROT), Rehabilitate, Lease or Rent, and Transfer (RLT), Build, Rehabilitate, Operate, and Transfer (BROT).

[63] The World Bank and PPIAF Database classifies Greenfield Projects as: Build, Lease, and Transfer (BLT), Build, Operate and Transfer (BOT), Build, Own, and Operate (BOO), Merchant Plants, Rental Plants.

### iv. Divestitures

With divestitures, a private entity purchases an equity stake in a state-owned entity, with the new operator being responsible for the operation, maintenance and investment. The World Bank and PPIAF Database (2008) classifies divestiture as either full or partial. Full divestiture implies that the state transfers 100 percent of the equity in the state enterprise to private entities, while with partial divestiture, the state transfers part of the equity in the state-owned company to private entities. With divestiture, the new operator assumes ownership of the assets, but based on the percentage of equity sold and conditions of the divestiture, the state may or may not retain full operational control of the project company.

Data on all the above private sector participation (PSP) variables was constructed based on 0/1 dummy variable. The switch from 0 to 1 in all cases is time dimensioned or dated, where a value of 1 is assigned if there exist any of the above PSP options, and zero otherwise.

### 5.2.3 Competition Variable

Based on the results of the survey[64] work on the African electricity market, it was observed that the installed generation capacities of most countries are below 1,000 MW and most of the markets are either in the single buyer mode. This implies that in Africa there is no robust competition 'in' the electricity wholesale market. Instead, there is competition 'for' the market.[65]

With competition 'for' the market, state-owned generators and *independent power producers (IPPs)* are allowed to compete for the construction of generation plants, through long-term contracts (Hunt and Shuttleworth 1997; Kessides 2004), as a way of simulating competition in the generation market (Arizu et al. 1997). The countries also accept bids for *private concessions and management contracts.* This implies that the PSP variables used for the analysis, are directly measuring the impact of competition 'for' the market. Therefore an attempt to separately model the impact of PSP and competition 'for' the market would amount to double-counting.

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[64] Also refer to the document, Gboney, W. (2006), "Power Sector Reforms in Africa: Emerging Lessons in Regulation, Competition and Privatisation".

[65] The concept of competition 'for' the market was invoked by Demsetz (1968), where robust competition 'in' the market was not possible.

## 5.3. Control Variables

### 5.3.1 Political Constraint

The measure of political constraint, POLCON, is taken from Henisz (2005). POLCON measures the extent to which a change in a political actor is constrained in his choice of future policies. In constructing the POLCON variable, Henisz (2005) first identified the number of independent branches of government, and also took into account, the extent of alignment across the various branches of government. He used data on the party composition of the executive and legislative branches. POLCON values range from zero (i.e. least constrained or most hazardous) to one (i.e. most constrained and not hazardous).

### 5.3.2 Economic Freedom of the World Index

The Economic Freedom of the World (EFW) Index was taken from the Economic Freedom of the World, Report by Gwartney, Lawson and Gartze.

The index measures the degree of economic freedom in the following five areas

i. Size of government expenditures, taxes and enterprises
ii. Legal structure and security of property rights
iii. Access to sound money
iv. Freedom to trade internationally
v. Regulation of credit, labour and business

For this research study, the ‘chain-linked’ economic freedom index has been used because that permits a much more precise comparison across time periods. According to Gwartney, Lawson, Gartzke (2006), the ‘chain-linked’ index methodology ensures that country’s ratings will change across periods only when there is a change in ratings for components during the overlapping years. Zhang et al. (2002) and Zhang et al. (2005) noted that the use of Economic Freedom as a control variable, can serve as a proxy for wider institutional factors associated with the success of market liberalisation, such as lower taxation and lesser restriction on foreign investment.

### 5.3.3 Rural population density and urbanisation percentage

These two demographic variables were taken from the World Bank’s World Development Indicators (2006). Rural population density is measured as the total rural population of a country (i.e. number of persons) divided by the total area (in square kilometres) of that country. Urbanization percentage measures the degree of a country's urbanization and it is calculated as the total urban population divided by the total population of a country.

### 5.3.4 Real GDP per capita and Industry Value Added as a percentage of GDP

The real Gross Domestic Product (GDP) per capita is measured in constant 2000 US dollars. The Industry value added as a percentage of GDP is the ratio of industrial sector value added of a country as a percentage of the GDP.

### 5.3.5 Export-to-Import Ratio

The export-to-import ratio measures the extent to which a country can meet its debt service obligations. A value greater than one indicates a higher probability of a country's ability to meet its debt service obligations. This ratio was calculated as:

Value of exports of goods and service by a country ÷ by the import value of goods and services

## 5.4 Network Sector Dependent Variables

### 5.4.1 Transmission System Loss.

The movement of electrical energy across the transmission system is inevitably associated with line loss, which is a function of the transmission network capacity, network congestion, as well as the line length. The transmission system loss level is defined as the percentage of energy generated which is lost in transmission. Electric Transmission Loss (%) for the econometric analysis was calculated as follows:

Transmission Loss (%) = (Total Transmission and Distribution Loss%) – (Distribution Loss%)

where:

- **Total Transmission and Distribution Losses(%)** = [(Total Generation Output – Total Amount of Electricity Distributed) x 100%] ÷ (Total Generation Output)
- **Total Transmission and Distribution losses** comprise all losses due to transport and distribution of electrical energy. It therefore includes losses in transmission between sources of generation and points of distribution to consumers.

### 5.4.2 Total Distribution System Loss

The total distribution system losses comprise both technical and non-technical losses. Technical losses refer to losses due to operation, and those due to distribution of electricity through heat and transformation, from one voltage level to the other. The technical loss component thus gives an indication of the technical quality of power supply arising from adequate network investment.

Non-technical losses consist of losses due to unmetered supply, illegal connections, theft and metering errors by the utility company. The level of non-technical losses, is thus a measure of the management efficiency of a distribution network company, and has a direct impact on the revenue collection from electricity sales. The total distribution system loss level is defined as:

$$\frac{(\text{Total electricity purchased} - \text{Total electricity sold and paid for by customers})\times 100}{(\text{Total electricity purchased by distribution company})}$$

# CHAPTER 6 ECONOMETRIC ESTIMATION AND RESULTS

## 6.1 Econometric Issues

A longitudinal or panel data set is one that follows a given sample of individuals over time, and provides multiple observations on each individual in the sample (Hsiao 2003). A panel data set thus contain repeated observations over time for individuals, firms, countries etc. (Windmeijer 2006). A typical panel data model can be formulated as follows:

$y_{it} = \beta x'_{it} + \eta_i + \varepsilon_{it}$

where:

$y_{it}$ = dependent variables

$x'_{it}$ = explanatory variables

$\eta_i$ = the unobserved constant individual effects

and i=1,…..N; t=1,…..T.

As noted by Hsiao (2003), since panel data involve two dimensions comprising a cross-section, N, and a time series, T, one expects the computation of panel data estimators to be more complicated than the analysis of cross-section data alone (where T=1) or time series alone (where N=1). The availability of panel data according to Hsiao (2003), has simplified the computation and making of inferences. Panel data sets are increasingly being used in applied work because they offer a lot of advantages over single time series or cross section data, and can also be used to fit econometric models which are more complex (Weinhold 1999; Semykina and Wooldridge 2005; Ashenfelter et al. 2003). It thus offers the researcher great flexibility in modelling differences in behaviour across individuals (Greene 2003).

One of the key attractions for the use of panel data sets is that their use can offer a solution to the problem of bias caused by unobserved heterogeneity, characterising economic agents (Ashenfelter et al. 2003, Hsiao 2003; Semykina and Wooldridge 2005; Windmeijer 2006). Unlike cross-section models, panel models can be used to control for the country-specific, time invariant characteristics through the use of country-specific intercepts or fixed effects (Weinhold 1999; Semykima and Wooldridge 2005; Greene 2003).

Furthermore, because panel data sets are generally associated with large data sets, they yield large degrees of freedom and may allow the detection of dynamics. They can therefore be used to examine issues which are not apparent from individual time series or cross section settings alone (Greene 2003). If the researcher can impose some condition of homogeneity upon the parameters across countries, then a panel data model will permit additional power and may allow the detection of relationships which are not apparent from individual time series (Weinhold 1999).

Panel data also possess an advantage over cross-section data since one cannot estimate dynamic models from observations at a single point in time, and it is rare for single cross-section surveys to provide enough information about earlier time periods, to pave the way for dynamic relationships to be investigated (Bond 2002). Bond (2002) also noted that panel data models offer better opportunity to investigate heterogeneity in adjustment dynamics between different types of individuals, household or firms.

As observed by Weinhold (1999), Semykina and Wooldridge (2005), Arellano (2003), Cubbin and Stern (2005), despite the afore-mentioned benefits, the use of panel data can give rise to the following problems:

- problem of coefficient heterogeneity
- dynamic nature of panel estimations
- endogeneity problem

These observed problems, as well as methods for dealing with them are discussed below:

### 6.1.1 Unobserved heterogeneity: Fixed Effects versus Random Effects

In discussing the various types of panel data, Greene (2003) considered the following regression model:

$y_{it} = x'_{it}\beta + z'_{i}\alpha + \varepsilon_{it}$

where:

$y_{it}$ = K dependent variables

$x'_{it}$ = K regressors, not including a constant term

$z'_{i}\alpha$ = heterogeneity or the individual effect and $z_i$ contains a constant term and a set of individual (i.e. unobserved or observed) variables.

According to Greene (2003), if $z_i$ contains a constant term, the model is known as pooled regression, and ordinary least square will provide consistent and efficient estimates of α and the slope vector β. In the fixed effects model, the main assumption is that there are unique unobservable attributes of an individual which are pre-determined and fixed (Ashenfelter et al. 2003). If $z_I$ is unobserved, but correlated with $x_{it}$ fixed effects panel data can be used to eliminate the potential bias introduced by the unobservable heterogeneity, and to estimate unbiased slope coefficients (Greene 2003; Ashenfelter et al. 2003) This assumption enables the intercept of the regression line to be shifted for each individual in a specific or a deterministic manner in the sample (Ashenfelter et al. 2003).

The last panel data model is the random effects approach, where the unobserved individual heterogeneity is assumed to be uncorrelated with the included variables or regressors $x_{it}$ (Greene 2003; Windmeijer 2006). With the random effects regression model, individual-specific characteristic is not constant but is treated as a random variable specific to that individual. The shifts of the intercepts in the regression model are not specific but randomly distributed across individuals (Ashenfelter et al. 2003).

If the panel model is specified as: $y_{it} = x'_{it}\beta + \eta_i + \varepsilon_{it}$
then according to Windmeijer (2006), the Random Effects specification assumes that $E(\eta_i) = 0$; $E(\eta_i/x_{it}) = 0$, implying that the individual effect, $\eta_i$ is uncorrelated with the regressors $x_{it}$.[66]

From above, it implies that: $E(y_{it}/x_{it}) = x'_{it}\beta + E(\eta_i/x_{it}) + E(\varepsilon_{it}/x_{it}) = x_{it}'\beta$

Though the random effects model has the advantage of not been associated with loss in degrees of freedom, one of the assumptions for its use which states that the unobserved individual effects (i.e. omitted country characteristics) are randomly drawn from a given distribution, may not be a reasonable one for the current study. This is because the units of observation and the sample consist of countries, which cannot be considered to represent a random sample of countries in Africa. The second assumption that the individual effects are uncorrelated with the included explanatory variables can be easily violated, hence the use of the fixed effects model for this research study.

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[66] This assumes that though the OLS estimator on the poled data is unbiased, it is not efficient, and the estimated standard errors are wrong, since it does not take cognisance of the dependence of the error term within individual over time. See details in Windmeijer, F. (2006), "A Course in Pane/Longitudinal Data Analysis", Centre for Microdata Methods and Practices (CEMMAP) and University of Bristol.

The use of fixed effects model for this research work makes it possible to circumvent the problem of potential bias, and allow the unobserved-country specific effects (i.e. omitted variables) to be correlated with any of the included explanatory variables. The use of the fixed effects for the research study will thus permit countries with unique characteristics and outcomes, to differ from others in a specific manner, since the intercepts for each country will also differ in a deterministic manner in the regression model.

### 6.1.2 Dynamic Panel Structure

Economic processes respond not only to current values of independent variables but also to past values, and so when effects persist over time, an appropriate model should include lagged variables (Greene 2003). Many processes including the electricity supply industry, possess a dynamic adjustment overtime. By not taking account of the dynamic aspect of data in the econometric modelling, this can lead to potential loss of important information and cause serious misspecification biases (Weinhold 1999). Weinhold (1999) also noted that the inclusion of lagged dependent variables in a model, can control to a large extent for omitted variables. According to Nerlove (2000), all models of economic behaviour are basically dynamic, whether or not the dynamic aspect is explicit. He argues that “current behaviour is almost always dependent on the state of the system describing it, and this state in turn, often depends on how it got to where it is”.

A typical dynamic panel data model containing lagged dependent variable to estimate behavioural relationship that are dynamic in nature, was specified by Hsiao (2003) as follows:

$$y_{it} = \alpha y_{i,t-1} + \beta' x_{it} + \alpha^*_i + \lambda_t + u_{it}, \quad i = 1, \ldots\ldots N$$
$$t = 1, \ldots\ldots, T$$

where:

$y_{it}$ = K x1 vector of dependent variables

$x_{it}$ = K x1 vector of explanatory variables, including the constant term

$\beta$ = K x 1 vector of constants

$\alpha^*_i$ , $\lambda_t$ = (unobserved) individual and time-specific effects, which are assumed to stay constant for given i over t, and for a given t over i

$u_{it}$ = (unobserved) variables that vary over t and i.

Short-run effect impact multiplier is = β[67]
Long-run, steady effect or equilibrium multiplier is = $\beta/(1 - \alpha)$

In the electricity sector for instance, since major capital investments are completed over one year and expected efficiency improvements are affected by past achievements, it is imperative that these adjustments are included in the econometric model. Such adjustment processes can be modelled by the inclusion of a lagged dependent variable (Hsiao 2003; Weinhold 2003; Windmeijer 2006; Cubbin and Stern 2005). Even in instances when the coefficients on the lagged dependent variables are not of direct interest, allowing for dynamics in the underlying process may be important for recovering consistent estimates of other parameters (Bond 2002).

The use of dynamic panel data in a fixed effects model can however give biased parameter estimates on the lagged dependent variable (Weinhold 1999; Bond 2002)[68] The second problem of dynamic models arises from the homogenous assumption which is often imposed on the coefficient of the lagged dependent variable, which can create biases, when in fact, the dynamics are heterogenous across the cross-section (Weinhold, 1999). To illustrate the issue of biased estimates, consider the simple dynamic model below:

$$y_{it} = \beta y_{t-l} + \gamma x_{it} + \varepsilon_{it}$$

where:

$$\varepsilon_{it} = \mu_i + \xi_{it}$$

i = 1,-----------,N across sector units

t = 1,-----------,T time periods

[67] According to Greene (2003), the accumulated effect, τ, periods later of an impulse at time t is $\beta_\tau = \sum_{i=0} \beta_i$

**68** As noted by Bond (2002), the OLS estimator of α (i.e. the coefficient of the lagged dependent variable) is inconsistent since $y_{i,t-1}$ is positively correlated with the error term $\lambda_i + u_{it}$ , due to the presence of he individual effects , and this correlation does not vanish as the number of individuals in he sample gets larger, nor does the correlation varnish as the number of periods increases. This makes the OLS estimators inconsistent form panels with large T. For much more detailed explanation see Bond, S. (2002), “Dynamic Panel Data Models: A Guide to Micro Data Methods and Practice”, Nuffield College, Oxford and Institute for Fiscal Studies, University College of London

According to Nickell (1981), even if the fixed effects or Least Squares Dummy Variable is used, $y_{t-l}$ would still be correlated with the error term, resulting in a bias of order 1/T. This assertion is supported by Hsiao (2003) and Andersen and Hsiao (1981). One approach that can be adopted is to use the Within Groups estimator[69], but according to Bond (2002), the estimators, can be inconsistent[70]. Furthermore, standard results for omitted variables bias indicate that at least in large samples, the Within Group estimator is biased downwards. Another suggested approach for dealing with this problem according to Weinhold (1999) is to use the first-differencing approach to the data, to remove $\mu_i$ to give:

$$y_{it} – y_{it-1} = \beta(y_{it-1} – y_{i,t-2}) + \gamma(x_{it} - x_{i,t-1}) + (\varepsilon_{it} - \varepsilon_{i,t-1})$$

or

$$\Delta y_{it} = \beta\Delta y_{it-1} + \gamma x\Delta_{it} + \Delta\varepsilon_{it}$$

This method or approach is known as the first-differenced Two Stage Least Squares (i.e. 2SLS) estimator for AR(1) panel data model, which was proposed by Anderson and Hsiao (1981, 1982). Because $\Delta y_{it-1}$ is correlated with the first difference error term, it is necessary to instrument for it. Andersen and Hsiao (1981) have suggested the use $\Delta y_{it-2}$ or $y_{it-2}$ as instruments, since these are not correlated with $\Delta\varepsilon_{it} = \varepsilon_{it} - \varepsilon_{it-1}$. Thus it is possible to obtain consistent estimates of β using 2SLS with instrumental variables that are both correlated with $\Delta y_{i,it-1}$ and orthogonal to $\Delta\varepsilon_{it}$. (Bond 2002)[71].

According to Weinhold (1999), in practice the inability to find good instruments for the first-differenced lagged dependent variable, can itself create estimation problems. This assertion is also reinforced by Kiviet (1995) who showed by using a broad range of Monte Carlo simulations that panel data models which use instrument variable estimation can result in poor finite sample efficiency and bias.

**69** This is achieved by first obtaining the mean values of $y_{it}$, $y_{i,t-1}$, $\lambda_i$ and $u_{it}$ across T-1 observations for each individual i. The next step is to express the original deviations as deviations from these individual means and OLS is used to estimate these transformed equations . Since the mean of the time invariant $\lambda_i$ is still $\lambda_i$, these individual effects are successfully removed form the transformed equations. See details of the mathematical formulation in Ashenfelter et al. (2003)

**70** For panels where the number of time periods available is small, the transformation to remove the individual effects rather induces a non-negligible correlation between the transformed lagged dependent variable and the transformed error term.

**71** The 2SLS estimator is consistent in large N, fixed T panels and identifies the autoregressive parameter β, provided, at least 3 time series observations are available (i.e. $T\geq3$). It is worthy to also note that the Within Groups estimator is also consistent when $T\geq3$. See details in Bond (2002).

Weinhold (1999) has however stated that as T gets larger, the biased estimate of the coefficient of the lagged dependent variable become less serious.

### 6.1.3 Problem of endogeneity

Consider a typical simple dynamic panel data model which is defined as:

$$y_{it} = \alpha y_{i,t-1} + \beta x_{it} + \eta_i + v_{it} \quad i = 1,2,\ldots\ldots\ldots N; \quad t = 2,3, \ldots\ldots\ldots\ldots\ldots\ldots T.$$

If $v_{it}$ is serially uncorrelated, then the $x_{it}$ series is *endogenous* if:

i. $x_{it}$ is correlated with $v_{it}$ and earlier shocks
ii. uncorrelated with $v_{i,t+1}$ and subsequent shocks

The issue of endogeneity has become important in recent econometric analysis related to Independent Central Banks (ICB), the telecommunications and electricity sectors.

$x_{it}$ is described as being *strictly exogenous* if it is uncorrelated with all *past, present and future* realisations of $v_{it}$. A key assumption for the OLS estimator, which minimises the sum of squared residuals to be a good, unbiased, estimator is that the regressors are exogenous, implying that they are uncorrelated with the error term. Quite often, it is possible for this assumption to be violated and the regressors become endogenous (Windmeijer 2006).

Consider this simple model adapted from Windmeijer (2006) to illustrate the problem of endogeneity, which examines the impact of education (i.e. number of years in full-time education) on wage.

$$\text{In wage} = \beta_0 + \beta_1 . \text{Education}_i + u_i$$

where:
$\beta_0$ = Constant
$u_i$ = Error term
$\beta_1$ = Unknown parameter to be estimated

Assuming the error term $u_i$ contains unobserved 'ability', then the above equation can be re-written as follows:

$$\text{In wage} = \beta + \beta_1 . \text{Education}_i + (\text{ability}_i + v_i)$$

If the unobserved 'ability' affects both wages and education level, then the OLS estimator for $\beta_1$ will be biased upwards, if Education and ability are positively correlated (i.e. endogenous). The problem of endogeneity can be resolved to provide unbiased and consistent estimates, using the method of instrumental variables (Windmeijer 2006), where a good instrument for the endogenous variable is one which:

iii. explains part of the variation in Education

iv. is uncorrelated with the error term, $u_i = ability_i + v_i$

The issue of endogeneity was considered in Gutiérrez (2003) and Cubbin and Stern (2005). The significance of endogeneity was reinforced by Wallsten (1999) when he stated that, though he assumed all the key reform variables to be strictly exogenous in his study on the telecommunications sector, he was of the opinion that in similar future studies, competition, privatisation and regulation must be endogenised. He supported his position by noting that it is possible that the same factors which influence changes in telecommunications sector are likely to also influence the reforms. Though Cubbin and Stern (2005, pg.18) acknowledged the problem of endogeneity, they however noted that "it should be well-handled by country specific effects".

Nevertheless, this study, in addition to treating the variables of interest as strictly exogenous, goes a step further to assume the reform variables to be endogenous in a simple dynamic model, using one-step Generalised Method of Moments[72] (1-Step GMM), and adopting the *method of orthogonal deviations,* developed by Arellano and Bover (1995). The method of orthogonal deviations uses equations in first differences to eliminate the *individual-specific effects and control for possible endogeneity.* It does not however introduce serial correlation induced by the

[72] According to Bond (2002), most empirical work tends to focus on the results for the one-step estimator instead of the two-step estimator. This is because simulation studies have suggested only modest efficiency gains from using the two-step estimator, even in the presence of heteroskedasticty. Furthermore, the dependence of the two-step weight matrix on estimated parameters makes the usual asymptotic distribution approximations less reliable for the two-step estimator. Results of simulation studies show that the asymptotic standard errors are either too small or the asymptotic t-ratios too big in the case of two-step estimator. When similar tests were however conducted on the one-step estimator, the results were quite accurate. See more detailed explanation in Bond (2002). See also Bond and Windmeijer (2002).

differencing, by applying a Generalised Least Square (GLS) transformation to the differenced data (Arellano and Bover 1995; Arellano 2003; Windmeijer 2006).

For this study, the basis for selection of instruments for the reform variables is based on Bårdsen et al. (2002) and Gutiérrez (2003) who noted that endogenous variables in levels, lagged two or more periods would be valid instruments, *provided there is no serial correlation in the error terms*. In the light of this, this study has used lagged differences for the reform variable for at least two years as instruments. It is worthy to note that even though the use of orthogonal deviations to estimate the GMM equations is expected to remove serial correlation, in order to ensure robust estimates, this study goes ahead to test for the presence of autocorrelation using the Q-statistic, by examining the correlogram of residuals over 6 lags, in the simple dynamic GMM equations.

## 6.2 Data Set for Generation Sector

The data set is a panel covering 25 African countries for 18 years (i.e.1988-2005). The list of countries in the sample is annexed as Appendix 2. The table showing list of countries with regulatory bodies and PSP options, and year of passage of energy or electricity law, is shown in Appendix 4. The choice of countries for the study was informed by the need to minimise *selection bias*[73], and ensuring that countries in the research sample are representative of the target population (i.e. African countries)[74] about which conclusions are to be drawn. The selection of countries also took into account, whether a country has a *regulatory body* and/or any of the *PSP options*, as well as accessibility to credible data and information, for both dependent and independent variables.

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**73** The use of a randomization technique to select the countries from the larger population ensures removal or elimination of selection and other biases. Jamison, W. (2000) recommends three quantitative techniques to achieve namely: Simple Random Sample, Systematic Sampling and Stratified Sampling. These methods ensure the representativeness from the entire population, by incorporating an element of randomness to the selection. See details in Jamison, W. (2000), “Sampling and Error: Does the Bad Apple Spoil the Whole Bunch”, http://www.wpi.edu/Dept/IGSD/IQP.

**74** The list of countries in the research sample cuts across those in the sub-regions namely: North Africa, West/Central Africa, East Africa and Southern Africa. The list also include countries which are relatively politically stable for a considerable period (i.e. South Africa, Ghana, Nigeria, Togo, Egypt etc), as well as those which have experienced brief or prolonged unstable political problems (Cote d’Ivoire, Rwanda, Zimbabwe etc.).

A complete list of variables used for the econometric modelling including the data sources, is shown in Appendices 3a, 3b and 3c. The correlation matrix and descriptive statistics are also annexed as Appendix 5 and Appendices 6-10 respectively. To ensure high level of data reliability, primary data and other information obtained from the research questionnaire was cross-checked with at least four different reliable sources.

## 6.3 Model Specification

Because countries differ in so many ways, the fixed effects model has been used to control for unobserved country-specific factors. The econometric specifications to which the data are applied are derived from the following generation investment model:

=f(Formal Regulatory Index, Informal Regulatory Index, Privatisation Dummy, POLCON, Economic Freedom, Real GDP per Capita, Industry Output as a % of GDP, Export-to-import ratio, Passage of Electricity Sector Law and Urbanization).

The use of the same model specification for the three generation performance measures draws from the literature and is based on similar empirical analysis by Ros (1999), Wallsten (1999, 2001), Cubbin and Stern (2005) and Zhang et al. (2002, 2005). Similar model and functional form has been used by Bergara et al (1997), Henisz and Zenith (2000, 2004)[75], as well as Gutiérrez (2003). The seemingly appeal for use of this functional form and model in the literature, is summarised by Cubbin and Stern (2005) when they noted that*, "there appears to be no obvious well-defined theoretical model on which to base a more sophisticated approach".* The static model in equation (1) below, where all the reform variables are treated as exogenous, is first used to first explore the impact of regulation, competition and privatisation on generation performance indicators (i.e. dependent variables).

$$\ln y_{it} = \alpha_o+\beta_1(FRI_{it})+\beta_2(IRI_{it})+\beta_3(C_{it})+\beta_4(P_{it})+\gamma X_{it}+v_i+\xi_{it} \quad \text{-----------------------------} (1)$$

where:

$\ln y_{it}$= The natural logarithm of generation sector performance indicators namely Per capita Installed Generation Capacity (kilowatt per person), Per Capita

[75] See also Gutiérrez (2003); Fink et al. (2002)

Generation Plant Energy Output (kilowatt-hours per person), Generation Plant Capacity Utilization.

$\alpha_o$ = Constant term

$v_i$ = Time-invariant or country specific fixed effect

FRI = Formal Regulatory Index

IRI = Informal Regulatory Index

$\xi_{it}$ = Error Term

P = Privatisation Dummy

$X_{it}$ = Control Variables namely: POLCON, Economic Freedom, Real GDP per capita, Industry Output as % of GDP, Export-to-import ratio, Urbanisation percentage and Passage of Electricity Law.

For all cases, the variables are defined for i = 1, -----------N countries over
t = 1, -----------T time periods

The inclusion of control variables (i.e. non-reform variables) such as POLCON, Economic Freedom, Real GDP per capita, Industry Output as a percentage of GDP, Export-to-Import ratio and urbanisation ratio, are all in line with the economics literature, where such variables have been found to be statistically significant. One expects that as GDP and industrial output as a percentage of GDP all increase, this will call for more generation capacity and higher plant utilization. The inclusion of economic freedom variable is to serve as a proxy for wider institutional factors associated with trade liberalization, lower taxation and reduce government incentives to expropriate the returns that the investor generates (Williamson 1976; Levy and Spiller 1994). If there are no institutions in a country to sufficiently constrain political actors, this could act as a disincentive to potential electricity producers to deploy capital to build the needed capacity (Henisz and Zelner 2000). The models thus include a measure of political constraints (i.e. POLCON) on executive discretion. The POLCON values are taken from Henisz (2005).

Evidence from the economics literature, show that privatisation alone cannot yield the desired results in electricity sector reforms. This require that competition and regulation are introduced to co-exist with privatisation, and ensure that the desired results are achieved. To test for the conditional effects will require that a multiplicative interaction terms are included in the econometric specification (Fredrich; 1982; Jaccardi, Turisi; and Wan 1990). This assertion is supported by Zhang et al. (2002) who suggested that in assessing the results of electricity sector reforms, the effects of privatisation, competition and regulation should be taken into account both separately (i.e. in an additive fashion) and in a combined or an interactive manner (i.e. in a multiplicative manner)[76]. In the light of the above, the econometric estimations offer the opportunity to explore the separate effects of the reform variables, and if necessary, also explore their interaction.

## 6.4 Generation Sector Results: Reform Variables Exogenous

The results of the econometric estimations for the generator sector are explored in this section. All the equations in this section were estimated using fixed effects static and dynamic models, where the key reform variables were assumed to be strictly exogenous. Section 6.4.1 examines the per capita installed generation capacity results, while sections 6.4.2 and 6.4.3 discuss the results on plant utilization and per capita generation plant energy output respectively.

### 6.4.1 Per Capita Installed Generation Capacity

For the results on per capita generation capacity, four equations are separately estimated for the static and dynamic models. On Electricity Sector Law, the variable is observed to be positively related to per capita installed generation capacity and statistically significant, at the 5% level in the static model. On regulation, FRI on its own, seem to have a positive and significant impact on installed generation capacity. When FRI and IRI are interacted, the variable is observed to be positively and significantly related to per capita installed generation capacity, at the 5% and 10% levels. It is worthy to note that the 1% significant level is achieved at lags of 3 and 6, for IRI and FRI respectively.

**Table 6.1 Results for Per Capita Installed Generation Capacity**

| Est Method | Fixed Effects: Static Model | | | | Fixed Effects: Dynamic Model | | | |
|---|---|---|---|---|---|---|---|---|
| Dep Variable= log(GenCap) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Constant | -4.2782*** (-93.4090) | -4.9944*** (-77.8997) | -4.8528*** (-53.3533) | -4.5821*** (-34.0417) | -0.0405)* (-1.7178) | -0.0288 (-1.3823) | -0.0298 (-1.4110) | -0.0641** (-2.3549) |
| Log(GenCap (-1)) | | | | | 0.9887*** (195.996) | 0.9911*** (203.308) | 0.9909*** (202.982) | 0.9779*** (155.845) |
| ELECT. LAW | | 0.0155** (2.2355) | | | | | | 0.0039 (0.5079) |
| FRI(-7) | | | 0.5167** (1.9713) | | | | | |
| IRI(-1)*FRI(-2) | | | | | | 0.0038** (2.2856) | 0.0037** (2.4341) | |
| IRI(-6) | | | 0.0572 (0.1636) | | | | | |
| IRI(-5)*FRI(-4) | | | | | 0.0016 (0.3661) | | | |

[76] See also Bergara et al (1997); Henisz and Zelner (2004)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **IRI(-3)*FRI(-6)** | | | | 0.0790*** (3.5165) | | | | |
| **IRI(-2)*FRI(-5)** | 0.0831* (1.7813) | | | | | | | |
| **MGMTLEASE (-1)** | | | | | | 0.0419** (2.2165) | | |
| **MGMTLEASE (-2)** | | | | | | | 0.04629** (1.9977) | |
| **MGMTLEASE (-7)** | | | | | 0.0975** (2.0665) | | | 0.1194** (2.2860) |
| **GREENFIELD** | | | | | | 0.0021 (0.1752) | 0.0050 (0.0766) | |
| **GREENFIELD (-10)** | 0.2163*** (3.0712) | | | | | | | |
| **DIVESTITURE** | 1.6545*** (26.6161 | | | 1.5644*** (28.1399) | | | | 0.0083 (0.5262) |
| **CONCESS(-1)** | | | | 0.0630 (0.1640) | | | | |
| **URBANIS.** | 0.0163*** (14.6533) | 0.0553*** (21.7749) | 0.0507*** (20.9492) | 0.0217 (6.7936) | | | | -0.0005 (0.2575) |
| **EXPIMP RATIO** | 0.0010*** (16.5923) | | | 0.0010*** (15.7298) | | | | |
| **ECON. FREEDOM** | | 0.0183*** (2.5147) | 0.0153 (1.3590) | | 0.0022 (0.9886) | | | |
| **POLCON** | | 0.3321** (2.4201) | | 0.6315*** (3.8571) | 0.0320 (1.3849) | 0.0272 (1.5021) | 0.0282 (1.5868) | 0.0534** (1.993) |
| **Long-run, steady state multiplier** | | | | | 88.4956 | 112.3596 | 109.8901 | 45.2489 |
| **Adj. R-Sqd.** | 0.6292 | 0.4580 | 0.4126 | 0.5896 | 0.9972 | 0.9956 | 0.9959 | 0.9969 |
| **S.E. of reg.** | 0.8052 | 1.033 | 1.0227 | 0.8578 | 0.0698 | 0.0901 | 0.0900 | 0.0725 |
| **F-Statistic** | 24.6159 | 13.600 | 11.7690 | 22.1286 | 5227.21 | 3603.40 | 360.124 | 3662.105 |
| **DW Statistic** | 0.0477 | 0.0539 | 0.0783 | 0.0703 | 1.8542 | 1.6416 | 1.6568 | 1.9034 |
| **Q-Statistics+ (examined at least 6 lags)** | | | | | insignific. (No serial Correl.) | insignific. (No serial Correl.) | insignific. (No serial Correl.) | insignific. (No serial Correl.) |
| **No. of Obs.** | 268 | 377 | 231 | 251 | 230 | 335 | 335 | 225 |

NB: t-statistics in parenthesis are robust to heteroskedasticity
***: statistically significant at 1%; ****:** statistically significant at 5%; ***:** statistically significant at 10%.
**+ :** If no serial correlation, Q-statistic should be insignificant and p-values should be large (i.e.>5%) at **all lags.**

This finding on regulation seem to suggest that in Africa, a considerable time is required after the establishment of a regulatory body, before one can expect an enhancement in per capita installed capacity. This finding also corroborates the assertion by Kessides (2004) that in developing countries, a considerable amount of time is required to build the regulatory capacity and develop a competent and well-trained work force in accounting, economic policy analysis, finance and law, even though the regulator may be strong in certain technical aspects. The results are generally consistent with the findings by Cubbin and Stern (2006) that both a regulatory law and higher quality regulatory governance are positively and significantly associated with higher per capita generation capacity.

On the impact of private sector participation (PSP), management and lease contracts lagged between 1 and 7 years, is found to be statistically significant at the 5% in all the dynamic model equations. The implication of this result is that since management and lease contract require the public authority or the state-owned utility company to be responsible for financing capital investments, it is likely to take at least 1 year before an enhancement in per capita installed generation capacity, can be expected. In the long-run, management and lease contracts have the potential to increase per capita installed generation capacity, by almost 54%.

The other PSP variables namely greenfield projects and divestiture (i.e. partial) are all positively related to the dependent variable and statistically significant at the 1% level. In the case of greenfield projects, the positive impact appears to be felt after 10 years, with the potential to increase installed generation capacity per capita, by almost 20%. This observation is consistent with the results by Zhang et al. (2002) who found that in the presence of independent regulation, privatisation in the generation sector increases generation capacity to reduce the threat of 'hold up'.

On the control variables, the effects of Polcon, Economic Freedom and Export-to-import ratio on per capita installed generation capacity are all positive and significant. This result seem to suggest that there is likely to be enhancement in generation capacity in countries with more economic freedom, higher political constraint on investment decisions by political actors . The result is also consistent with the findings by Zelner and Henisz (2001) that higher levels of political constraint will increase investment, by reducing government expropriation, thereby encouraging private sector participation in the generation sector.

One observation from the results in table 6.1 above is the low Durbin-Watson Statistic from the static models, which seem to suggest the presence of serial or autocorrelation. Though autocorrelation can still lead to unbiased estimators, it could yield incorrect standard errors and thus lead to over-estimating the t-statistics for hypothesis testing. The dynamic models have also been estimated as part of the econometric analysis to ensure that the results and inferences are fairly robust.

It is however worthy to note the limitation of the Durbin-Watson (DW) statistic in the dynamic model (i.e. if there is a lagged dependent variable on the right-hand side of the equation). In such a situation, the DW statistic is no longer valid for testing for autocorrelation (EViews Users's Guide 2004). To overcome this limitation, the Q-statistic has been used to check for serial correlation in the residuals for the dynamic model, by examining the correlogram of residuals over 6 lags. For the Q-statistic test, If there is no serial correlation in the residuals, *the autocorrelation and partial correlation at each lag should be nearly zero, and the Q-statistic for all lags should be insignificant, with the reported p-values being large* (EViews User's Guide 2004).

### 6.4.2 Generation Plant Utilisation

The econometric results on generation plant utilization in table 6.2 below shows that unlike IRI, the estimated coefficient on FRI is positive but statistically insignificant. This result implies that FRI on its own, does not appear to enhance plant capacity utilisation. When FRI and IRI are interacted, the interaction term appears to have a positive and a significant impact on the dependent variable. The coefficient was found to be statistically different from zero at the 1% level, and this was achieved at higher lags of up to 9 years for FRI and 2 years for IRI. In the long-run, the existence of a regulatory agency seems to enhance plant utilization by about 28%. The finding implies that impact of regulation on plant utilisation is likely to be felt after considerable number years of establishment of the regulatory agency.

On PSP, partial divestiture, concessions and greenfield projects all seem to be associated with enhancement in plant utilization. The coefficient on partial divestiture is statistically significant at both 1% and 10% levels, while the estimated coefficient on concession is significant at the 1% level.

**Table 6.2 Results for Generation Plant Utilization**

| **Est. Method** | **Fixed Effects: Static Model** | | | | **Fixed Effects: Dynamic Model** | | | |
|---|---|---|---|---|---|---|---|---|
| **Dep. Variable = log(Plant Utiliz)** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** |
| **Constant** | -0.3114*** (-8.6366 | -0.8149*** (-8.2217) | -0.8072*** (-9.4770) | -0.3528*** (-4.6957) | -0.0165 (-0.1871) | -0.0167 (-0.1893) | 0.0140 (0.1717) | -0.1351 (-1.2879) |
| **Log(Plant Utiliz(-1))** | | | | | 0.9101*** (33.2118) | 0.9073*** (32.4129) | 0.9069*** (40.1023) | 0.8845*** (32.5440) |
| **FRI(-6)** | | | | | 0.0052 (0.2882) | | | |
| **FRI(-8)** | | | 0.0970 (1.4628) | | | | | |
| **IRI(-2)** | | | 0.0583** (2.2080) | | | | | |
| **FRI(-5)*IRI(-4)** | | | | 0.0523*** (3.7359) | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **FRI(-6)*IRI(-4)** | 0.0646*** (3.9741 | | | | | | | |
| **FRI(-8)*IRI(-2)** | | 0.1095*** (15.4544) | | | | | | |
| **FRI(-9)*IRI(-6)** | | | | | | | | 0.0322*** (7.2558) |
| **DIVESTITURE** | | 0.2851*** (17.5407) | | | 0.0279* (1.6447) | 0.0291* (1.8041) | | 0.0372*** (3.3634) |
| **CONCESS.** | | 0.4578*** (10.2327) | | | | | | |
| **CONCESS.(-1)** | | | | | | | | 0.1133*** (6.2951) |
| **GREENFIELD** | | | 0.0706* (1.6437) | | | | | |
| **URBANIS** | 0.0011 (0.9419) | -0.0049*** (-2.6767) | -0.0035* (-1.6588) | 0.0007 (0.3869) | 0.0007 (0.4879) | 0.0006 (0.4869) | 0.0010 (0.8165) | -0.0001 (-0.1185) |
| **log(Indout gdp)** | -0.1917*** (-8.0636) | | | -0.1919*** (-8.3839) | -0.0326** (-2.2414) | -0.0327** (-2.2751) | -0.0330** (-2.4105) | |
| **Log(RGDPPC)** | | 0.0135 (0.5570) | 0.0097 (0.4322) | 0.0079 (0.3574) | 0.0044 (0.2149) | 0.0040 (0.1998) | -0.0042 (-0.2190) | 0.0081 (0.3425) |
| **Long-run, steady state multiplier** | | | | | 11.1235 | 10.7875 | 10.7411 | 8.6580 |
| **Adj. R-Sqd.** | 0.1279 | 0.1414 | 0.0404 | 0.1167 | 0.8673 | 0.8675 | 0.8665 | 0.8248 |
| **S.E. of regression** | 0.2607 | 0.2522 | 0.2667 | 0.2639 | 0.1060 | 0.1057 | 0.1026 | 0.1119 |
| **F-Statistic** | 3.2000 | 3.0536 | 1.5628 | 2.8974 | 75.1716 | 80.1029 | 89.0185 | 53.7459 |
| **DW Statistic** | 0.1992 | 0.3269 | 0.2198 | 0.1825 | 2.0865 | 2.0843 | 2.1059 | 2.0038 |
| **Q-Statistic+ (examined at least 6 lags)** | | | | | insignific. (No serial Correl.) | insignific. (No serial Correl.) | insignific. (No serial Correl.) | insignific. (No serial Correl.) |
| **No. of Obs.** | 226 | 188 | 188 | 245 | 226 | 226 | 245 | 220 |

NB: t-statistics in parenthesis are robust to heteroskedasticity
***: statistically significant at 1%; ****:** statistically significant at 5%; ***:** statistically significant at 10%.
**+ :** If no serial correlation, Q-statistic should be insignificant and p-values should be large (i.e. >5%) at **all lags.**

The coefficient on greenfield project was statistically different from zero at the 10% level. In the long-run, the enhancement from greenfield project is about 24%.
This result corroborates the finding by Zhang et al. (2002, 2005) that in the presence of a regulatory agency, privatisation is associated with higher levels of plant utilization.

### 6.4.3 Per Capita Generation Energy Output

In both the static and dynamic model results on per capita generation energy output, shown in table 6.3 below, the coefficient on electricity sector law was positive and statistically significant at the 1% and 10% levels. This result was achieved at lags of at least 6, which seems to suggest that in African countries, it may take at least 6 years after the enactment of the law, before one can expect an enhancement in per capita generation energy output.

Turning to the effects of regulation, the results seem to suggest that FRI on its own, is likely to enhance plant output. When the interaction variable of FRI and IRI is considered, there appears to be a positive relationship, which was statistically significant at the 1% level, in both the static and dynamic models. The long-run effect is estimated to be about 6%. The result was obtained at about 7 years for FRI and after 3 years for IRI.

The implication of this result is that though electricity sector law and regulation may seem to have a positive and significant impact on plant, it appears this favourable result can be achieved after a considerable period of time of establishing the regulatory framework. The results are consistent with those by Cubbin and Stern (2005) when they observed that the existence of a regulatory body with good governance characteristics does not only improve electricity sector outcomes in principle, but actually do so in practice.

**Table 6.3 Results for Per Capita Generation Energy Output**

| **Est. Meth.** | **Fixed Effects: Static Model** | | | | **Fixed Effects: Dynamic Model** | | | |
|---|---|---|---|---|---|---|---|---|
| **Dep. Var. =log(Gen. output)** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** |
| **Constant** | -0.7671 (-1.0903) | 0.4957 (0.6207) | 0.4297 (0.6232) | 0.7072 (1.1321) | -0.4821 (-0.9778) | -0.9824* (-1.7658) | -0.4411 (-0.8819) | -0.0803 (-0.1583) |
| **Log(Genoutput(-1))** | | | | | 0.8073*** (10.5464) | 0.8265*** (12.5330) | 0.7959*** (10.7328) | 0.6711*** (6.9718) |
| **ELECTLAW (-6)** | | | | | | 0.0443* (1.7660) | | |
| **ELECTLAW (-7)** | 0.0776*** (2.8790) | | | | 0.0472* (1.7971) | | | |
| **ELECTLAW (-8)** | | 0.1090*** (5.1966) | | | | | | |
| **FRI(-7)** | | | | | | | 0.0256** (2.0731) | |
| **IRI(-5)** | | | | | | | 0.0019 (0.2031) | |
| **FRI(-7)*IRI(-3)** | | | | | | | | 0.0207*** (2.6286) |
| **FRI(9)*1R1 (-7)** | | | 0.0372*** (2.4696) | 0.0422*** (3.525) | | | | |
| **MGTLEASE (-3)** | 0.1915*** (5.3645) | 0.1322*** (3.2592) | | | | | | |
| **MGTLEASE (-4)** | | | | | | | 0.0890*** (2.9929) | |
| **MGTLEASE (-5)** | | | | | | 0.1275*** (4.5467) | | |
| **MGTLEASE (-8)** | | | | | | | | 0.1208* (1.7571) |
| **CONCESS. (-2)** | 0.04124 (0.7742) | | | | | | | 0.0083 (0.2573) |
| **GREEN FIELD(-1)** | | | 0.1059*** (2.6664) | 0.1067*** (2.6794) | | | | |
| **GREEN FIELD(-4)** | | | | | | 0.0526** (2.1332) | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **GREEN FIELD(-9)** | | 0.0652 (0.8308) | | | | | | 0.0877* (1.6653) |
| **DIVEST(-6)** | | | | | | 0.0951* (1.7310) | | |
| **DIVEST(-8)** | | 0.0736*** (2.5348) | 0.0711* (1.7140) | | | | | |
| **MGTLEASE (-3)** | | | 0.1494*** (3.2445) | 0.1496*** (3.1571) | | | | |
| **POLCON** | -0.0760** (-2.3836) | | | | -0.0609* (-1.9088) | | | |
| **log(RGD PPC)** | 0.7559*** (5.5570) | 0.5201*** (4.1946) | 0.5200*** (4.3299) | 0.5061*** (4.3654) | 0.2073*** (2.7665) | 0.2770*** (3.3972) | 0.2021*** (2.8311) | 0.2192** (1.9751) |
| **Log(Indout gdp)** | 0.0307 (0.2114) | 0.3326*** (5.5758) | 0.3316*** (4.6789) | 0.3614*** (5.5856) | 0.1254* (1.6083) | 0.0025 (0.0323) | 0.1009 (1.3037) | 0.1205 (1.2253) |
| **Urbanis** | | | | | -0.0049* (-1.7646) | 0.0036 (0.5633) | -0.0025 (-0.7553) | |
| **Urbanis(-3)** | | 0.0067 (0.6651) | 0.0077 (1.3189) | | | | | |
| **Long-run, steady state multiplier** | | | | | 5.1894 | 5.7637 | 4.8996 | 3.0404 |
| **Adj. R-Sqd.** | 0.9883 | 0.9900 | 0.9901 | 0.9902 | 0.9959 | 0.9958 | 0.9960 | 0.9949 |
| **S.E. of regression** | 0.1692 | 0.1584 | 0.1581 | 0.1571 | 0.0992 | 0.1010 | 0.0987 | 0.1021 |
| **F-Statistic** | 417.6352 | 415.1559 | 416.4960 | 448.8809 | 1223.339 | 1216.003 | 1236.226 | 1003.315 |
| **DW Statistic** | 0.5061 | 0.6380 | 0.6602 | 0.6618 | 2.1287 | 1.9370 | 2.1447 | 2.0540 |
| **Q-Statistic+ (exam. at least 6 lags)** | | | | | insignific. (No serial Correl.) | insignific. (No serial Correl.) | insignific. (No serial Correl.) | insignific. (No serial Correl.) |
| **No. of Obs.** | 209 | 209 | 209 | 209 | 209 | 228 | 209 | 209 |

NB: t-statistics in parenthesis are robust to heteroskedasticity
***: statistically significant at 1%; ****:** statistically significant at 5%; ***:** statistically significant at 10%.
**+ :** If no serial correlation, Q-statistic should be insignificant and p-values should be large (i.e. >5%) at **all lags.**

The result on PSP variables shows that management and lease contract, greenfield project and partial divestiture are all positively and significantly related to per capita plant energy output. Greenfield project seems to enhance plant output after 1 year, while management and lease contract do so after 3 years. The result also seems to imply that partial divestiture is likely to enhance plant output after 6 years. On the size of the effects, management and lease contracts appear in the long-run to enhance per capita plant energy output by at least 36%, while greenfield projects seem to increase per capita energy output by almost 30%.

## 6.5 Generation Sector Results: Reform Variables Endogenous

In this section, an attempt is made to endogenise the reform variables using 1-step Generalised Method of Moments (1-step GMM), making use of instrumental variables, which are correlated with the reform variables, but uncorrelated with the error term. The results from the endogenous model are then compared with those from the exogenous (i.e. fixed effects models) to ascertain whether there is evidence of serious endogeneity, to cause a significant change in the findings made in the fixed effects model (i.e. exogenous model).

On per capita installed generation capacity, the results in table 6.4, seem to indicate that both FRI and IRI when considered separately or allowed to co-exist (at higher lags), appear to enhance installed plant capacity. Turning to plant utilization, when the interaction between FRI and IRI is considered at lags of 4 and 9 respectively, the variable is noted to positively and significantly related at the 1% and 5% levels.

The results on generation energy output show that at higher lags, the coefficient on FRI, IRI and Electricity Sector Law are all positively and significantly related with the dependent variable. These findings are consistent with those obtained in the fixed effects model.

On the effects of the PSP variables, the results seem to indicate that greenfield project is likely to enhance installed plant capacity, but after 10 years. The result seem to support the notion that competition 'for' the market in Africa countries is likely to  encourage private sector participation in the generation segment of the electricity market..

**Table 6.4 Generation Sector Results: Endogenous Reform Variables**

| Dep Var. | Log(GenCap) | | | Log(PlantUtiliz) | | | Log(Genoutput) | | |
|---|---|---|---|---|---|---|---|---|---|
| Est. Method | 1-Step Generalised Method of Moments | | | 1-Step Generalised Method of Moments | | | 1-Step Generalised Method of Moments | | |
| | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 |
| log(Gen cap(-1)) | 0.7651***<br>(15.0573) | 0.7740***<br>(13.1151) | 0.7895***<br>(15.4991) | | | | | | |
| Log (Plant Utiliz(-1)) | | | | 0.5806***<br>(4.7282) | 0.6247***<br>(6.2483) | 0.5239***<br>(5.2724) | | | |
| log(Genoutput(-1)) | | | | | | | 0.8798***<br>(14.4752) | 0.8138***<br>(10.7623) | 0.7984***<br>(11.9440) |
| FRI(-2) | | | 0.0159*<br>(1.7449 | | | | | | |
| IRI(-2) | | | 0.0252**<br>(2.2004) | | | | | | |
| FRI(-6) | | | | | | | | | 0.0070*<br>(1.6722) |
| IRI(-8) | | | | | | | | | 0.0707**<br>(2.0649) |
| FRI(-7) | | | | | | | | 0.0106*<br>(1.7043) | |
| IRI(-1) | | | | | | | | 0.0159*<br>(1.6957) | |
| FRI(-4)*IRI(-3) | 0.0140**<br>(2.0429) | | | | | | | | |
| FRI(-4)*IRI(-9) | | | | 0.0209*<br>(1.7150) | 0.0361***<br>(3.7183) | | | | |
| FRI(-8)*IRI(-8) | | | | | | 0.0364*<br>(1.8694) | | | |
| ELECTLAW(-7) | | | | | | | 0.0129*<br>(1.6863) | | |
| GREENFIELD | | | | | | | | 0.0131***<br>(3.5034) | |
| GREENFIELD(-10) | 0.0656**<br>(2.0898) | | | | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **DIVEST(-6)** | | | | | | | 0.0744** (2.1027) | | |
| **MGTLEASE(-1)** | | | | | 0.0695** (2.1292) | | | | |
| **MGTLEASE(-5)** | | | | | | | | 0.1734*** (4.6218) | |
| **MGTLEASE(-10)** | | | | | | 0.0721* (1.8959) | | | |
| **POLCON** | 0.0988 (0.6935) | 0.0362 (0.2508) | 0.0630 (0.5299) | | | | | | |
| **log(Urban)** | 0.2759* (1.6591) | 0.1903* (1.9178) | 0.1438 (1.5487) | 0.3026 (1.0319) | 0.4535 (1.0336) | 0.2920 (0.8150) | | | |
| **log(rgdppc)** | | | | 0.1987 (1.0763) | 0.1661 (0.8708) | 0.0818 (0.4562) | 0.3395*** (2.6226) | 0.4246*** (3.8577) | 0.3634*** (2.5476) |
| **log(Indout gdp)** | | | | 0.0047 (0.0333) | | | | | |
| **ECONFREED** | | 0.03876*** (2.9122) | | | | | | | |
| **EXPIMP(-7)** | | | -0.0010* (-1.7824) | | | | | | |
| **Long-run, steady state multiplier** | 4.2571 | 4.4248 | 4.7506 | 2.3844 | 2.6645 | 2.1004 | 8.3195 | 5.3706 | 4.9603 |
| **S.E. of regress.** | 0.0688 | 0.0701 | 0.0682 | 0.1060 | 0.1060 | 0.1038 | 0.1004 | 0.1000 | 0.1032 |
| **Q-Stat + (exam. at least 6 lags)** | insignific. (No serial Correl.) | insignific. (No serial Correl.) | insignific. (No serial Correl.) | insignif. (No serial Correl.) | Insignific. (No serial Correl.) | insign, (No serial Correl.) | insignific. (No serial Correl.) | insignif. (No serial Correl.) | insignific. (No serial Correl.) |
| **No. of Observ.** | 200 | 208 | 208 | 200 | 208 | 231 | 220 | 230 | 230 |

NB: t-statistics in parenthesis are robust to heteroskedasticity

***: statistically significant at 1%; ****:** statistically significant at 5%; ***:** statistically significant at 10%.

**+ :** If no serial correlation, Q-statistic should be insignificant and p-values should be large (i.e. >5%) at **all lags.**

On the impact of PSP variables on generation energy output, management and lease contracts, greenfield project and partial divestitures all appear to have a positive and significant impact. These results are consistent with the fixed effects model. On plant utilization, management and lease contract is observed to be positively related to plant utilization and statistically different from zero at the 5% and 10% levels.

## 6.6 Network Sector: Reform Variables Exogenous

### 6.6.1 Data Set

The data set is a panel covering 25 African countries for 18 years (i.e.1988-2005). A complete list of variables used for the econometric modelling including the data sources, is shown in the table below.

**Table 6.5 Data sources for Transmission and Distribution System Losses**

| Dependent Variable | Data Source |
|---|---|
| Total Transmission and Distribution Losses | Primary data from country responses to research questionnaire, US Energy Information Administration (EIA, 2006), African Energy Policy Research Network (AFREPREN), World Development Indicators (World Bank, 2006) |

### 6.6.2 Transmission Sector Results

This section discusses the transmission system loss results, where the key reform variables are assumed to be strictly exogenous for both static and dynamic models. As shown by the results in table 6.6 below, Energy Sector Law (ESLAW) is inversely related to transmission network loss, with the estimated coefficient being significantly different from zero at the 1% level. ESLAW, on its own, appear to reduce transmission network loss level by almost 20%. At a lag of 2, the co-existence of ESLAW with either FRI and IRI appear to significantly reduce transmission network loss level.

**Table 6.6 Results for Transmission Sector**

| Estimation Meth. | Fixed Effects: Static Model | | | | Fixed Effects: Dynamic Model | | | |
|---|---|---|---|---|---|---|---|---|
| Dep. Var= log(Transloss) | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 |
| Constant | -3.5807*** (-6.5073) | -3.0615*** (-7.4235) | -3.5365*** (-6.1097) | -3.5372*** (-6.2752) | -2.5673*** (-5.4063) | -4.4729*** (-8.0431) | -2.8448*** (-5.6281) | -2.6392*** (-4.9721) |
| log(Transm loss(-1)) | | | | | 0.3580*** (3.2045) | 0.2821* (1.8314) | 0.3572*** (2.7903) | 0.3608*** (3.1692) |
| ESLAW | -0.1196*** (-2.6551) | -0.1761*** (-3.8401) | -0.1188*** (-2.5855) | | | | | |
| ESLAW(-1) | | | | | -0.1310*** (-2.9359) | | | -0.1218*** (-3.5425) |
| ESLAW(-2)* FRI(-3) | | | | | | | -0.0442*** (-3.0606) | |
| ESLAW(-2)* IRI(-8) | | | | | | -0.1209** (-2.2194) | | |
| FRI(-2)*IRI | -0.0166** (-2.0257) | | | | | | | |
| FRI(-3)*IRI(-1) | | | -0.0212*** (-2.4723) | -0.0293*** (-3.4350) | | | | |
| Greenfield | -0.0217 (-0.4405) | | -0.0251 (-0.4989) | -0.0631 (-1.0788) | | -0.1506 (-1.5423) | -0.0501 (-1.1040) | -0.0221 (-0.4952) |
| log(RGDPCAP) | 0.0609 (0.7510) | -0.0391 (-0.6192) | 0.1049 (1.0910) | 0.0873 (0.9782) | 0.0806* (1.8644) | 0.2937*** (4.8836) | 0.1321* (1.7330) | 0.0852 (1.3909) |
| log(urbanis) | 0.0535 (0.6134) | 0.0723 (0.9940) | | -0.0046 (-0.0407) | 0.0438 (0.5499) | 0.0992*** (3.0620) | | 0.0482 (0.5587) |
| log(rpopdens) | | | -0.0217 (-0.3925) | -0.0015 (-0.0327) | -0.0072 (-0.2010) | 0.0302 (0.8733) | 0.0162 (0.4285) | |
| Polcon | 0.3413*** (5.9810) | 0.4175*** (7.6306) | 0.3329*** (4.9858) | 0.2426*** (4.8626) | 0.2431*** (3.6975) | | 0.1506** (2.4233) | 0.2393*** (3.6878) |
| Long-run, steady state multiplier | | | | | 1.5576 | 1.3930 | 1,5556 | 1.5645 |
| Adj. R-Sqd. | 0.7676 | 0.7726 | 0.7673 | 0.7599 | 0.8128 | 0.7788 | 0.7954 | 0.8013 |
| S.E. of regression | 0.2415 | 0.2399 | 0.2430 | 0.2471 | 0.2179 | 0.2479 | 0.2279 | 0.2235 |
| F-Statistic | 42.1600 | 53.4476 | 40.0361 | 37.9410 | 59.1922 | 28.1396 | 47.0239 | 54.4658 |
| DW Statistic | 1.3620 | 1.3008 | 1.3114 | 1.2572 | 2.1070 | 2.0349 | 2.0295 | 2.1067 |
| Q-Statistic+ (examined at least 6 lags) | | | | | insignific. (No serial Correl.) | insignific. (No serial Correl.) | insignific. (No serial Correl.) | insignific. (No serial Correl.) |
| No. of Obs. | 300 | 356 | 285 | 281 | 336 | 286 | 285 | 319 |

NB: t-statistics in parenthesis are robust to heteroskedasticity
***: statistically significant at 1%; ****:** statistically significant at 5%; ***:** statistically significant at 10%.
**+ :** If no serial correlation, Q-statistic should be insignificant and p-values should be large(i.e. >5%) at **all lags**

In the long-run, the co-existence of ESLAW and FRI is likely to reduce the network loss level by 7%, while the co-existence of ESLAW and IRI seems likely to drive down loss level by almost 17%.

It is also worthy to note that though the regulatory indices on their own, do not seem to reduce transmission loss level, when they are allowed to co-exist, they appear to have a significant impact on loss reduction. The estimated coefficient is statistically significant at the 1% and 5% levels.

The analysis also sought to investigate the impact of greenfield project or IPPs on transmission network loss level. Though the estimated coefficient on greenfield project is negative, it is not significantly different from zero. This implies that greenfield projects, on their own, do not appear to have a direct and significant impact on network loss reduction. This result further means that with the *single-buyer or vertically integrated market* model associated with African electricity markets, the incumbent generator which also owns the transmission company, enters into a long-term power purchase agreement (PPAs) with IPPs. This market structure can however be a limitation because it does not permit the IPP to sign a direct contract with an unbundled transmission company. This structure does not therefore incentivise greenfield power operators, to exert direct pressure on the transmission company to strive for network efficiency by reducing loss level.

On the control variables, real GDP per capita appears likely to increase network loss levels by almost 40%. The result implies that as the level of economic activity of a country improves, this is associated with overloaded network and transformers and hence higher technical loss levels. To ensure that loss level is kept low, it is imperative the timely investments are made at the right locations, to relieve the network of congestion.

### 6.6.3 Distribution Sector Results

The results on the distribution system total loss level are shown below in table 6.7. The results show the estimated coefficient on ESLAW to be inversely related to total distribution loss level, and statistically significant at the 5% and 10% levels in the static model. It is also noted that the two regulatory indices, whether on their own or in co-existence, do not appear to significantly reduce total distribution system loss level.

Management and lease contracts as a PSP option, appears to be a key driver of distribution loss reduction. In the long-run, Management and Lease Contract seems to reduce the loss level by almost 20%. It is also noted that though the estimated coefficient on concession contract is negatively related to distribution loss level, it does not appear to have a significant impact on distribution loss reduction.

**Table 6.7 Results for Distribution Sector**

| Estimation Method | Fixed Effects: Static Model | | | Fixed Effects: Dynamic Model | |
|---|---|---|---|---|---|
| Dependent Variable = log(Distribloss) | 42 | 43 | 44 | 45 | 46 |
| Constant | -2.1852** (-2.4422) | -3.6001*** (-7.6710) | -3.1534*** (-5.2095) | -0.7438 (-1.549) | -1.5086** (-2.3363) |
| Log(Distribloss(-1)) | | | | 0.5416*** (3.8061) | 0.5218*** (3.5167) |
| ESLAW(-3) | | -0.0717** (-2.0458) | | | |
| ESLAW(-4) | | | -0.0536* (-1.6727) | -0.0099 (-0.3764) | |
| FRI(-5) | | | | | -0.0032 (-0.1692) |
| FRI(-7) | | -0.0036 (-0.2032) | | | |
| FRI(-7)*IRI(-3) | -0.0001 (-0.0556) | | | | |
| MGTLEASE(-2) | | | -0.1391*** (-3.3175) | | |
| MGTLEASE(-3) | -0.1688*** (-3.6186) | -0.1441*** (-3.0112) | | -0.0923*** (-2.6205) | -0.1094*** (-3.1657) |
| CONCESS | | | | -0.0019 (-0.0865) | -0.0100 (-0.3978) |
| CONCESS(-2) | -0.0063 (-0.2277) | | | | |
| Log(rpopdens) | -0.1016 (-0.6291) | | -0.0535 (-0.5444) | -0.0771 (-0.7629) | |
| Log(Urbanis) | 0.0532 (0.3598) | 0.2954** (2.2692) | 0.2809*** (3.5380) | | 0.0479 (0.3466) |
| Log(Indoutgdp) | | | -0.0277 (-0.8988) | | 0.0395 (0.5398) |
| Long-run, steady state multiplier | | | | 2.1815 | 2.0911 |
| Adjusted R-Sqd. | 0.8339 | 0.8386 | 0.8284 | 0.8749 | 0.8752 |
| S.E. of regression | 0.1849 | 0.1863 | 0.1810 | 0.1535 | 0.1574 |

| | | | | | |
|---|---|---|---|---|---|
| **F-Statistic** | 45.9756 | 45.2883 | 54.1202 | 75.8842 | 69.3615 |
| **DW Statistic** | 1.1288 | 1.1883 | 0.9706 | 2.3500 | 2.4091 |
| **Q-Statistic+ (exam at least 6 lags)** | | | | all p-values insignif. (No serial Correl.) | all p-values insignif. (No serial Correl.) |
| **No. of Obs.** | 216 | 200 | 254 | 258 | 235 |

NB: t-statistics in parenthesis are robust to heteroskedasticity
***: statistically significant at 1%; ****:** statistically significant at 5%; ***:** statistically significant at 10%.
**+ :** If no serial correlation, Q-statistic should be insignificant and p-values should be large (i.e. >5%) at **all lags.**

The results from the fixed effects model seem to indicate that even though the presence of a regulatory agency is necessary, its presence may not be sufficient to significantly reduce distribution system loss level. Effective loss reduction is likely to be achieved if management and lease contract is introduced into the distribution segment of the Electricity Supply Industry (ESI), as a PSP option.

On the control variables, urbanisation appears to significantly increase total distribution losses. This implies that as the urban population increase, it is necessary that the local distribution networks and transformers are upgraded to meet load growth, and hence reduce technical loss level. To ensure overall distribution loss reduction, the network loss reduction effort should be accompanied by commercial loss reduction such as controlling illegal connections and metering errors, as well as improving revenue collection.

## 6.7 Network Sector Results: Reform Variables Endogenous

In this section, the results from the endogenous model are examined and compared with those from the fixed effects (i.e. exogenous model), to ascertain whether there is serious evidence of endogeneity. The results from table 6.8 show that ESLAW on its own, appear to have a significant effect on transmission network loss reduction. The long-run effect is estimated to be 14% in the endogenous model. On the regulatory framework indices, even though the indices on their own, do not seem to reduce transmission network loss level, their co-existence appears to drive down transmission loss by almost 10%. The results on ESLAW and the regulatory indices from the endogenous model, seem to reinforce those from the fixed effects model.

**Table 6.8 Results for Network Sector: Reform Variables Endogenous**

| Estimation Method | 1-Step Generalised Method of Moments (GMM) | | | 1-Step Generalised Method of Moments (GMM) | | | |
|---|---|---|---|---|---|---|---|
| **Dependent Variable** | **Log(Transmloss)** | | | **Log(Distribloss)** | | | |
| | **47** | **48** | **49** | **50** | **51** | **52** | **53** |
| **Log(Transmloss (-1))** | 0.2595*** (18.1690) | 0.2106*** (8.6560) | 0.2287*** (11.2709) | | | | |
| **Log(Distribloss (-1))** | | | | 0.3337*** (11.1007) | 0.3289*** (11.0547) | 0.3313*** (10.2263) | 0.3536*** (11.2458) |
| **ESLAW(-1)** | -0.1024*** (-7.0842) | -0.0606** (-2.1589) | -0.0405** (-2.3602) | | -0.0100 (-0.6563) | | |
| **ESLAW(-5)** | | | | -0.0168 (-0.4872) | | -0.0054 (-0.1732) | |
| **FRI(-5)*IRI(-4)** | | | -0.0069** (-2.2018) | | | | |
| **FRI(-4)*IRI(-5)** | | -0.0078*** (-3.4122) | | | | | |
| **GREENFIELD (-5)** | -0.0262*** (-7.1052) | | | | | | |
| **MGTLEASE(-4)** | | | | -0.2056*** (-3.9544) | | | |
| **ESLAW(-3) *MGTLEASE(-4)** | | | | | | | -0.2067*** (-3.6463) |
| **FRI(-3) *MGTLEASE(-3)** | | | | | | -0.0796*** (-4.5674) | |
| **IRI(-3) *MGTLEASE(-3)** | | | | | -0.0727** (-2.2632) | | |
| **CONCESS(-3)** | | | | | -0.0269 (-0.4949) | | -0.0571 (-1.1982) |
| **CONCESS(-4)** | | | | -0.0056 (-0.1832) | | | |
| **log(rgdppcap)** | | | | -0.3232** (-2.4531) | | | |
| **log(rpopdens)** | | | | | -0.1384* (-1.8457) | -0.2563*** (-2.8994) | -0.0121 (-0.2276) |
| **log(Urbanis)** | | | | 0.5246*** (2.7049) | | 0.4019*** (3.0517) | 0.2191*** (3.2109) |
| **Polcon** | 0.2181*** (6.9378) | 0.0976 (1.2868) | -0.0119 (-0.1615) | | 0.0928*** (2.6569) | | |
| **Long-run, steady state multiplier** | 1.3504 | 1.2668 | 1.2965 | 1.5008 | 1.4900 | 1.4954 | 1.5470 |
| **S.E. of regression** | 0.2349 | 0.2397 | 0.2449 | 0.1568 | 0.1563 | 0.1614 | 0.1575 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Q-Statistic + (examined at least 6 lags)** | all p-values insignific. (No serial Correl.) | all p-values insignific. (No serial Correl.) | all p-values insignific. (No serial Correl.) | all p-values insignific. (No serial Correl.) | all p-values insignific. (No serial Correl.) | all p-values insignific. (No serial Correl.) | all p-values insignific. (No serial Correl.) |
| **No. of Observ.** | 228 | 228 | 228 | 216 | 258 | 216 | 235 |

NB: t-statistics in parenthesis are robust to heteroskedasticity
***: statistically significant at 1%; ****:** statistically significant at 5%; ***:** statistically significant at 10%.
**+ :** If no serial correlation, Q-statistic should be insignificant and p-values should be large (i.e. > 5%) at **all lags.**

On the impact of greenfield project, the results seem to indicate that at a higher lag of at least 5, the PSP variable may indirectly contribute towards reducing transmission network loss level. This is possible if an IPP signs a take-or-pay contract with the incumbent generator, which also owns the transmission network. Under this scenario, it is possible that the generator company, may at one stage in its operation, attempt to optimise power sales to the distribution companies and bulk industrial customers to meet unserved demand, by reducing transmission network loss level.

The results on the distribution sector show that even though ESLAW is necessary, it is not likely on its own, to significantly reduce total loss levels, unless the market permits PSP in the distribution sector. When management and lease contract is interacted with ESLAW, the estimated coefficient is found to be statistically significant at the 1% level, with the long-run loss reduction estimated to be 32%. When FRI or IRI is allowed to co-exist with management and lease contract, the long-run reduction effect is estimated to be about 12%. Though concession is negatively related to distribution system loss level, the estimated coefficient is observed to be statistically insignificant.

The results from the endogenous model on the distribution system corroborate those obtained in the fixed effects model, thus suggesting absence of serious evidence of endogeneity.

# CHAPTER 7 DISCUSSION AND CONCLUSIONS

## 7.1 Discussions

The empirical results from the study seem to reinforce those from Cubbin and Stern (2005), Zhang et al. (2002) and Zhang et al. (2005) that the establishment of a regulatory agency and private sector participation in the electricity sector does have a long-term beneficial impact on electricity sector outcomes. The study also found that the favourable outcomes seem to be achieved at higher lags associated with the key reform variables. This implies that in Africa and most developing countries, the regulatory agencies are fragile and it will take quite sometime for the regulatory frameworks to be fully developed before they can have any significant impact on electricity sector outcomes. This section reviews the main findings vis-à-vis the hypothesis which was formulated for the study.

### 7.1.1 Generation Sector

***Hypothesis 1a: Regulation will increase per capita installed generation capacity, plant utilization and per capita plant output.***

The effect of having an autonomous regulation established by electricity sector law was found to be positively related to each of the generation sector performance indicators. For installed generation capacity, the positive outcome is achieved after 2 and 6 years, for the formal and informal regulatory indices (FRI and IRI) respectively. On plant utilization, the results show that autonomous regulation does appear to enhance utilization rate, but once again, this is achieved after 7 years for IRI and 9 years for FRI. The estimated long-run effect is of the order of 28%. The results on plant energy output seem to suggest that regulation does have positive impact, and this is likely to be achieved after 3 years for IRI and 7 years for FRI.

The higher lags associated with FRI and IRI seem to reinforce the assertion by Kessides (2004) and Eberhard (2005) that in Africa, a considerable amount of time is required to build the core competencies of the technical and other professional staff of the regulatory agencies. The empirical results seem to support the hypothesis, but with a caveat that regulation will enhance per capita installed generation capacity, plant utilization and per capita plant output, only after the agency has been in existence for sometime to enable it build the necessary capacity.

***Hypothesis 1b: In the presence of regulation, private sector participation in generation will enhance per capita installed plant capacity and actual plant output.***

The regression results seem to identify management contracts, greenfield project and partial divestiture as the PSP options which are likely to enhance installed capacity and plant output, on per capita basis, but at higher lags. For management contracts, the result was statistically significant at the 10% level or better, while for greenfield project, the significance level was 1%. For installed plant capacity, the favourable outcomes were achieved after at least 1 year for management and lease contracts, and 10 years for greenfield project. On plant output, greenfield project seem to bring about favourable results after 1 year, 3 years for management contracts and 6 years for partial divestiture.

Though the empirical results seem to support the hypothesis that the PSP does enhance installed capacity and actual plant output, these results are likely to be achieved after number of years of market reforms and passage of electricity sector law, which permit private sector participation in the generation segment of the Electricity Supply Industry.

***Hypothesis 1c: Competition 'for' the market or private sector participation in generation, will lead to higher plant utilization.***

On plant utilization, partial divestiture, concessions and greenfield projects all seem to bring about favourable outcomes. The implication of this result is that competition 'for' the market or private sector participation in the market, is likely to bring about innovation and introduce modern maintenance practices, to reduce plant down-time and enhance plant utilization rate. The empirical results thus support the hypothesis.

### 7.1.2 Transmission Sector

***Hypothesis 2a: The co-existence of Energy Sector Law and regulatory agency, will lead to reduction in transmission system loss level.***

Energy Sector Law (ESLAW) appear to reduce transmission system loss level by almost 20%, with the result being statistically significant at the 1% level. When ESLAW is interacted with FRI at a lag of 2, the variable seem to have a significant impact on network loss reduction by almost 10%, while the co-existence with IRI appear to reduce average network loss level by 17%. The results thus support the hypothesis that co-existence of ESLAW, and autonomous regulatory agency is likely to have a significant and a positive effect towards reducing transmission network loss level. This favourable outcome is likely to happen after at least 2 years of establishment of a regulatory agency.

***Hypothesis 2b: The existence of a regulatory agency will reduce transmission network loss level.***

The empirical results seem to indicate that though none of the regulatory indices on their own, seem to reduce transmission network loss, when FRI and IRI was interacted, the variable appear to significantly reduce network loss level. The estimated coefficient is found to be statistically significant at the 1% or 5% levels, with the long-run reduction effect estimated to be 10%. This result is achieved after at least 4 years in the endogenous model. The results seem to support the hypothesis that the existence of a regulatory agency is likely to contribute to network loss reduction, but this outcome is achieved after a period of 4 years of existence of the agency, and if the agency is associated with good formal and informal attributes.

### 7.1.3 Distribution Sector

***Hypothesis 3a: Energy Sector Law and presence of autonomous regulation will lead to reduction of total distribution system loss level.***

The results indicate that though passage of Energy Sector Law (ESLAW) and regulation are necessary, they may not be sufficient to cause a reduction in the total distribution loss level. Though the econometric estimation seems to support the hypothesis, better outcomes are likely to emerge if, ESLAW and regulation co-exist with management and lease contract.

***Hypothesis 3b: Private Sector Participation will lead to lower total distribution system loss level.***

The econometric results on the distribution network seem to indicate that management and lease contract as a PSP option is likely to make a significant contribution towards total distribution system loss reduction. As the empirical results show, better outcomes are likely to emerge after 2 years of existence of management and lease contract. Concessions, though negatively related to the dependent variable, do not however appear to significantly reduce total distribution loss level.

## 7.2 Conclusion

This study has used panel data econometric analysis for 25 African countries, covering the period 1988-2005, to ascertain the effects of regulation, competition and private sector participation on electricity sector outcomes. The study was carried out using fixed effects model, where all the reform variables were assumed to be strictly exogenous, and 1-step GMM, where all the reform variables were assumed to be endogenous.

The results have to a large extent reinforced the notion that even though the sole existence of effective independent regulatory agencies in the African countries is necessary, this may not be sufficient to achieve the desired outcomes. The results seem to indicate that favourable outcomes are more likely to be achieved after considerable number of years of existence of the regulatory agency. The result also brings to the fore the notion that the non-availability of key skills in the various disciplines in a regulator agency can serve as a limiting factor. It is therefore imperative that the capacities of professional staff are well-developed to operate whatever systems and regulatory frameworks are chosen.

Though one of the goals of Power Sector Reforms in all countries is to improve the overall sector efficiency and quality of service, the thesis has not been able to explore the impact of quality of service because of lack of credible and reliable data in this area. Most African countries do not possess the necessary network automation, remote controls and computerized systems such as the Supervising, Control and Data Acquisitions (SCADA) system, for effective monitoring of quality of service factors. Therefore an attempt to use other proxies for quality of service may affect the robustness of the econometric results. This fear was confirmed by Estache et al. (2006), who used transmission and distribution losses as proxies of technical quality in their empirical studies. As part of their econometric findings, they stated that “the econometric work reported casts doubt on the conclusions reached from the basic data analysis”.

Similarly, the impact of the reforms on prices could not be investigated because of problem of data reliability. The impact of prices and quality of service in Africa's power sector therefore remains an area for future empirical analysis which would require further investigations.

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# Appendices

## Appendix 1: Questionnaire

### Appendix 1A: Legal and Regulatory Framework

**Has Parliament passed any law aimed at reforming the Power**
**Power?**

**If yes, list the following:**
Electricity Reform Law Year:
Electricity Reform Law name:
Actual Starting year of reform:

**Does the law allow the entry of new Independent Power Producers (IPPs)?**

**Does the law allow the electricity sector or any segments of the sector to be privatised in part or in whole?**

**REGULATORY REFORMS:**

**1**

**Was the regulatory body set by a decree or legislation?**

**Are the regulatory functions clearly spelt out in Primary legislation or in any other relevant document?**

**Can the Minister overrule the regulator?**

**2**

**Is the regulatory body a separate department within the Ministry or a body independent of the Ministry or government?**

**How are members of the regulatory commission appointed?**

**If the President or Ministry appoints the Chairman/Commissioners, is Parliamentary approval required?**

**On what grounds can commissioners be dismissed?**

**How is the regulatory body financed?**

**3**

**Is there an appeals mechanism for challenging regulatory decisions?**
**Has the body been used since its inception to challenge any regulatory decisions?**

**Is there a legal right of redress?**

**Does the regulatory body submit annual reports to Parliament or any other body?**

**Does the regulator have to answer questions in Parliament or appear before a Parliamentary sub-committee to answer questions?**

**4**

**Does the regulator involve key stakeholders in major decisions or proposed approach to taking major decisions through seminars, workshops etc.**

**Does the regulator conduct public hearings prior to tariff decisions?**

**Have responses from stakeholders' meetings, seminars and workshops influenced the regulator's decision?**

**5**

**Can the public get access to key regulatory documents such as licenses, Acts, rate-setting guidelines etc.?**
**How do people get access to these guidelines?**

**Does the law require the regulator to publish decisions?**
**If yes, where?**

**Does the regulatory body publish reasons behind major decisions in practice?**
**If yes, where?**
**If decisions are not published, are the affected parties told of the reasons for the major reasons?**

**6**
**If yes, what is involved?**

**Is it easy to change the key regulatory documents such as licenses, Acts,?**
**If yes, what is involved?**

**Are the principles involved in tariff setting set out formally in a document such as rate-setting guidelines?**

**7**

**Is the regulatory body headed by a single person or by a commission?**

**What is the number of employees at post compared to the required/expected professional staff level?**

**Professional staff:**
Economist:
Lawyers:
Engineers:
Accountants:
Financial Analysts:
Regulatory Economists:
Technicians:

| |
|---|
| **Non-Professional Staff**<br>Secretaries:<br>Drivers:<br>Others: |

**8**

| |
|---|
| **Has the regulatory body designed a standardized financial/technical Performance information format?**<br>**If yes, where is it published?**<br><br>**Can the regulatory body compel financial/technical and performance information from the utility companies?**<br><br>**Has the regulatory body designed a standardized Quality of Service Reporting Format?**<br>**If yes, where is it published?**<br><br>**Can the regulatory body compel Quality of Service performance information from the utility companies?**<br><br>**Is the information provided by the utility companies audited by the regulator or by independent auditors?**<br><br>**Has the regulator published regulatory accounting guidelines?**<br>**If yes, where** |

## Appendix 1B: Price Regulation

| PRICE REGULATION |
|---|
| **Is there an agency with the power to determine prices?**<br>**If yes, what is the name of the agency?**<br>**Which of the price components are determined?**<br><br>**Who monitors the end-user prices?**<br><br>**How often are prices reviewed?**<br>**(once in a year, once every two years or five years etc)**<br><br>**Are the prices cost reflective?**<br><br>**What is the principle for price regulation?** |
| **AVERAGE END-USER TARIFF LEVELS:**<br>**(in cents/kWh)-Please provide answers for 1988-2005** |
| **Residential Consumers:**<br><br>**Commercial Consumers:**<br><br>**Industrial Consumers:** |

## Appendix 1C: Industry Structure

| **INDUSTRY STRUCTURE: PRIVATISATION AND COMPETITION** | **ANSWER** | |
|---|---|---|
| **What is the existing electricity market model?**<br>(Vertically Integrated, Single-buyer model, Partial Retail Competition and Full Retail Competition etc.)<br><br>**Have the state-owned or municipal utilities corporatised?**<br><br>**Which of the following best describes the company?**<br>Full unbundling<br>Partial Unbundling<br>Full Integration<br>**If partial unbundling, please explain**<br><br>**What type of separation exist between generation and transmission?** (Legal Separation, Accounting Separation or No Separation).<br><br>**Indicate Years the following Activities were initiated:**<br>Privatisation<br>Vertical Unbundling<br>Entry of first IPP<br>Wholesale Market (I.e. Pool, Contracts, Spot etc.) | | |
| **OWNERSHIP: Please provide answers for 1988-2005** | **No of Companies** | **% of total System MW.** |
| **Generation Sector:**<br>Public Ownership<br>Majority Public Ownership (at least 50% of total shares)<br>Majority Private Ownership (at least 50% of total shares)<br>Private Ownership<br>What % of the company is owned by foreign investors?<br>**Transmission Sector:**<br>Public Ownership<br>Majority Public Ownership (at least 50% of total shares)<br>Majority Private Ownership (at least 50% of total shares)<br>Private Ownership<br>**Distribution Sector:**<br>Public Ownership<br>Majority Public Ownership (at least 50% of total shares)<br>Majority Private Ownership (at least 50% of total shares)<br>Private Ownership<br>What % of the company is owned by foreign investors? | | |
| **Are consumers allowed a choice of their own suppliers?**<br><br>**If yes, please complete the table below:** | | |
| **Customer Type: Please provide answers for 1988 - 2005**<br><br>Industrial: | **(kWh or KW)** | **System Consumption** |

| | | |
|---|---|---|
| Commercial:<br>Residential: | | |

| | ANSWER: |
|---|---|
| Does a Management Contract exist between a state-owned utility company and the private sector?<br><br>Has there been a Greenfield investment?<br>If yes, when? | |

| LICENSING: | ANSWER: | |
|---|---|---|
| Do there exist a formal process for granting license to generators,<br>transmission or distribution companies?-Yes/No<br><br>Who approves the license?<br><br>What is the effective licence period?<br><br>Can a license be revoked?-Yes/No<br><br>If yes, for what reasons are the licenses revocable? | | |

**Appendix 1D: Generation Sector- Please provide answers for 1988 - 2005**

| |
|---|
| **Installed Generation Capacity in MW.**<br>**Thermal:**<br>Oil Fired<br>Natural Gas Fired<br>Coal Fired<br>Diesel Fired<br><br>**Hydro:**<br><br>**Renewable Energy:**<br>**Others:**<br>**State the Peaking Plant:**<br>**TOTAL:** |

| |
|---|
| **Total Energy Generated (GWh):**<br>**Thermal: Please provide answers for 1988 – 2005**<br>Oil Fired<br>Natural Gas Fired<br>Coal Fired<br>Diesel Fired<br><br>**Hydro: Please provide answers for 1988 – 2005**<br>**Renewable Energy: Please provide answers for 1988 – 2005**<br><br>**Others:**<br><br>**TOTAL:** |

| **Thermal Efficiency (%):Please provide answers for 1988 - 2005** |
|---|
| **Thermal:**<br>Oil Fired<br>Natural Gas Fired<br>Coal Fired<br>Diesel Fired |

| |
|---|
| **Generation Ownership Status: Please provide answers for 1988 – 2005**<br>**Name of Company 1:**<br><br>**Market Share (%):**<br>Ownership Status (i.e. 100% State-owned,<br>Majority state-owned(>50%), Majority private-<br>owned (>50%), 100% Private-owned.<br>What proportion is owned by foreign investors? |

| **Employee Status:** |
|---|
| Total Number of Full time Employees:<br>Total Number of part-time Employees: |

## Appendix 1E: Transmission Sector- Please provide answers for 1988 - 2005

| |
|---|
| Is there separate ownership between generation and transmission?<br><br>Does the Electricity law or Power Sector require non-discriminatory access to the transmission system? (Yes or No)<br><br>Are there Guidelines for determining open-access rates/interconnections for all open-customers? (Yes or No)<br><br>If yes, how are the rates determined? (i.e. regulated or negotiated?)<br><br>Who controls the transmission access and approves applications? (Is it the regulator, Independent System Operator, Transmission or Generating Company?)<br><br>How are conflicts related to access and interconnection resolved? |

| |
|---|
| **Technical Loss (in GWh):**<br>(Total GWh Generated less Total GWh Sold to Dist. Companies and Bulk Customers) |

| |
|---|
| **Technical Loss (in %):**<br>(Total GWh Generated less Total GWh Sold to Dist. Companies/BC)*100<br>Total GWh Generated |

| |
|---|
| **Transmission Availability:**<br>Transmission System Availability (%): |
| **Transmission Circuit Kilometers:**<br>Total Transmission Circuit Kilometers |

## Appendix 1F: Distribution Sector- Please provide answers for 1988 - 2005

| |
|---|
| Does the law or sector reforms require non-discriminatory access to the distribution system?<br><br>Are there guidelines for determination of open-access rates/connection?<br><br>Who determines the access rates?<br><br>Who controls the transmission access and approves applications? (Is it the regulator, Independent System Operator, Transmission or Generating Company?)<br><br>How are conflicts related to access and interconnection resolved? (By the regulator, the Ministry etc.) |

| |
|---|
| Total Number of employees in the Distribution Company |
| **Total Number of Connected Customers:**<br>Sub-Transmission or High Voltage (State Voltage Level:)<br><br>Medium Voltage (State Voltage Level:)<br><br>Residential/ Low Voltage (State Voltage Level:) |

**Performance Indicators: Technical**

| |
|---|
| **Distribution System Losses:** |
| **Distribution Technical Loss (in GWh):**<br>(Total GWh Bought by Distribution Comp -Total GWh Billed) |
| **Technical Loss (in %):** |
| (Total GWh Bought -Total GWh Billed)* 100<br>Total GWh Bought |
| |

| |
|---|
| **Non-Technical Loss (in GWh):** |
| (Total GWh Billed by Distribution/Retail Comp -Total GWh translated into actual revenue) |
| **Non-Technical Loss (in %):** |
| (Total GWh Billed -Total GWh translated into revenue)* 100<br>Total GWh Billed) |

| |
|---|
| **Performance Indicators: Commercial**<br>**Revenue Collection Rate (%):**<br>(Total Actual Sales Collected as revenue in Local Currency)*100<br>(Total Sales Billed in Local Currency) |

| |
|---|
| **Revenue Collection Period:**<br>Average Receivable Collection Period (in days): |

| |
|---|
| **Electricity Accessibility Levels in %:**<br>Urban<br>Rural |
| **TOTAL (%):** |

## Appendix 2: List of Countries

| | |
|---|---|
| | |
| 1 | Algeria |
| 2 | Angola |
| 3 | Cameroon |
| 4 | Cote d'Ivoire |
| 5 | Egypt |
| 6 | Ethiopia |
| 7 | Gabon |
| 8 | Gambia |
| 9 | Ghana |
| 10 | Kenya |
| 11 | Malawi |
| 12 | Mali |
| 13 | Morocco |
| 14 | Nigeria |
| 15 | Mozambique |
| 16 | Namibia |
| 17 | Rwanda |
| 18 | Senegal |
| 19 | South Africa |
| 20 | Tanzania |
| 21 | Togo |
| 22 | Tunisia |
| 23 | Uganda |
| 24 | Zambia |
| 25 | Zimbabwe |

**Appendix 3a: Dependent Variables and Data Sources**

| Dependent Variable | Data Source |
|---|---|
| Per capita Installed Generation Capacity (kilowatt per person) | Primary data from country responses to research questionnaire, US Energy Information Administration (EIA, 2006), African Energy Policy Research Network (AFREPREN), World Development Indicators (World Bank, 2006) |
| Per Capita Generation Plant Output (kilowatt-hours per person) | Primary data from country responses to research questionnaire, US Energy Information Administration (EIA, 2006), African Energy Policy Research Network (AFREPREN), |
| Generation Plant Utilization (i.e. Load Factor) | Primary data from country responses to research questionnaire, US Energy Information Administration (EIA, 2006), African Energy Policy Research Network (AFREPREN), |

**Appendix 3b: Independent Variables and Data Sources**

| Independent Variables | Sources of data |
|---|---|
| Formal Regulatory and Informal Regulatory Index | Was constructed based on information from country responses and information from research questionnaire, Acts and Laws on Electricity Sector Reforms for countries, AFREPREN. |
| Privatisation Options | World Bank/PPIAF PPI Database (2008) |

**Appendix 3c: Control Variables and Data sources**

| **Control Variables** | **Sources of Data** |
|---|---|
| Passage of Electricity Law | Responses to research questionnaire, AFREPREN, Electricity Sector Acts and Laws for countries. |
| Political Constraint | Henisz (2005) |
| Economic Freedom | Economic Freedom of the World Report (2005) -Gwartney, Lawson and Gartzke |
| Real GDP per capita, Industry output as a percentage of GDP, Export-to-Import ratio, Rural Population Density, Urbanization percentage. | World Development Indicators (World Bank, 2006) |

**Appendix 4: Regulatory Bodies and Private Sector Participation (PSP) Options**

| | Country | Energy Sector Law* | Regulatory Body established outside Ministry | Greenfield Projects (i.e. IPPs) | Mgmt. & Lease Contracts | Concession | Divestiture |
|---|---|---|---|---|---|---|---|
| | | Yes = 1.00<br>No = 0.00 | Yes = 1.00<br>No = 0.00 | Yes = 1.00<br>No = 0.00 | Yes = 1.00<br>No = 0.00 | Yes = 1.00<br>No = 0.00 | Yes = 1.00<br>No = 0.00 |
| 1 | Algeria | 1.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0.00 |
| 2 | Angola | 1.00 | 0.00** | 0.00[a] | 0.00 | 0.00 | 0.00 |
| 3 | Cameroon | 1.00 | 1.00 | 0.00 | 0.00 | 1.00 | 0.00 |
| 4 | Cote d'Ivoire | 1.00 | 1.00 | 1.00 | 0.00 | 1.00 | 0.00 |
| 5 | Egypt | 1.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0.00 |
| 6 | Ethiopia | 1.00 | 0.00** | 0.00 | 0.00 | 0.00 | 0.00 |
| 7 | Gabon | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 |
| 8 | Gambia | 1.00 | 1.00 | 0.00 | 1.00 | 0.00 | 0.00 |
| 9 | Ghana | 1.00 | 1.00 | 1.00 | 1.00 | 0.00 | 0.00 |
| 10 | Kenya | 1.00 | 1.00 | 1.00 | 1.00 | 0.00[j] | 1.00 (partial) |
| 11 | Malawi | 1.00 | 1.00 | 0.00[b] | 1.00 | 0.00 | 0.00 |
| 12 | Mali | 1.00 | 1.00 | 0.00 | 0.00 | 1.00 | 0.00 |
| 13 | Morocco | 1.00 | 0.00 | 1.00 | 0.00 | 1.00 | 0.00 |
| 14 | Nigeria | 1.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0.00 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **15** | **Mozambique** | 1.00 | 0.00 | 0.00 | 0.00 | 0.00[e] | 0.00 |
| **16** | **Namibia** | 1.00 | 1.00 | 0.00 | 1.00 | 0.00 | 0.00 |
| **17** | **Rwanda** | 1.00 | 1.00 | 0.00 | 1.00 | 0.00 | 0.00 |
| **18** | **Senegal** | 1.00 | 1.00 | 1.00 | 0.00 | 1.00 | 0.00 |
| **19** | **South Africa** | 1.00 | 1.00 | 0.00[c] | 0.00 | 0.00[f] | 0.00[g] |
| **20** | **Tanzania** | 1.00 | 1.00 | 1.00 | 1.00 | 0.00 | 0.00 |
| **21** | **Togo** | 1.00 | 1.00 | 0.00 | 0.00 | 1.00 | 0.00 |
| **22** | **Tunisia** | 1.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 |
| **23** | **Uganda** | 1.00 | 1.00 | 0.00[d] | 0.00 | 1.00 | 0.00 |
| **24** | **Zambia** | 1.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00[h] |
| **25** | **Zimbabwe** | 1.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00[i] |

**Sources: Private Sector Participation (PSP) Options: World Bank & PPIAF, PPI Project Database (2008). (http://ppi.worldbank.org)**
**Energy Sector Law and Regulatory Bodies: Author's construction**

***: New or Amended, **: Regulatory Body present, but accountable to the sector Ministry. a, b, c, d: Greenfield Projects present but considered insignificant for modeling impact**

**j, e, f: Concession present but considered insignificant for modeling impact on reforms**
**g, h, i: Divestitures are insignificant for the purpose of modeling impact on reforms**

## Appendix 5: Correlation Matrix

| | COMPFMKT | CONCESS | DIVEST | ECON FREED | ELECT LAW | EXPIMP | FRI | GENCAPP | GREEN FIELD | IRI | MGMTLEASE | POLCON | URBANIS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **COMPFMKT** | 1.0000 | 0.0503 | 0.468524 | 0.201652 | 0.088200 | 0.063842 | 0.329851 | 0.209897 | 0.0224 | 0.321891 | 0.03384 | 0.411441 | -0.034978 |
| **CONCESS** | 0.0503 | 1.0000 | -0.028861 | -0.014672 | -0.023135 | -0.065915 | 0.116344 | -0.037455 | -0.0558 | 0.108979 | -0.03650 | 0.060761 | -0.019129 |
| **DIVEST** | 0.4685 | -0.0288 | 1.000000 | 0.151031 | 0.211186 | 0.027036 | 0.323848 | 0.249565 | -0.1199 | 0.360586 | -0.07837 | 0.207481 | -0.013124 |
| **ECONFREED** | 0.2016 | -0.0146 | 0.151031 | 1.000000 | 0.120399 | 0.394854 | 0.276839 | 0.259765 | 0.3374 | 0.258017 | 0.18566 | 0.249704 | 0.402589 |
| **ELECTLAW** | 0.0882 | -0.0231 | 0.211186 | 0.120399 | 1.000000 | 0.096714 | 0.071241 | 0.065720 | 0.0129 | 0.060918 | -0.01713 | 0.109913 | 0.178089 |
| **EXPIMP** | 0.0638 | -0.0659 | 0.027036 | 0.394854 | 0.096714 | 1.000000 | -0.004584 | 0.627722 | 0.0925 | -0.035304 | 0.22101 | 0.089978 | 0.624141 |
| **FRI** | 0.3298 | 0.1163 | 0.323848 | 0.276839 | 0.071241 | -0.004584 | 1.000000 | 0.105531 | 0.1472 | 0.867386 | 0.09388 | 0.302077 | -0.130445 |
| **GENCAPP** | 0.2098 | -0.0374 | 0.249565 | 0.259765 | 0.065720 | 0.627722 | 0.105531 | 1.000000 | -0.0684 | 0.169877 | -0.00077 | 0.125156 | 0.312944 |
| **GREENFIELD** | 0.0224 | -0.0558 | -0.119913 | 0.337415 | 0.012953 | 0.092568 | 0.147214 | -0.068491 | 1.0000 | 0.196964 | 0.15624 | 0.116750 | 0.169618 |
| **IRI** | 0.3218 | 0.1089 | 0.360586 | 0.258017 | 0.060918 | -0.035304 | 0.867386 | 0.169877 | 0.1969 | 1.000000 | 0.07675 | 0.224458 | -0.138288 |
| **MGMTLEASE** | 0.0338 | -0.0365 | -0.078377 | 0.185660 | -0.017139 | 0.221015 | 0.093883 | -0.000771 | 0.1562 | 0.076755 | 1.00000 | -0.164958 | 0.076814 |
| **POLCON** | 0.4114 | 0.0607 | 0.207481 | 0.249704 | 0.109913 | 0.089978 | 0.302077 | 0.125156 | 0.1167 | 0.224458 | -0.16495 | 1.000000 | -0.002539 |
| **URBANIS** | -0.0349 | -0.0191 | -0.013124 | 0.402589 | 0.178089 | 0.624141 | -0.130445 | 0.312944 | 0.1696 | -0.138288 | 0.07681 | -0.002539 | 1.000000 |

## Appendix 6: Descriptive Statistics - Per Capita installed Generation Capacity

| | COMP FMKT | CONCESS | DIVEST | ECON FREED | ELECT LAW | EXPIMP | FRI | GENCAPP | GREEN FIELD | IRI | MGMT LEASE | POL CON | URBANIS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mean** | 0.22015 | 0.013263 | 0.058355 | 4.170532 | 0.949161 | 894.4368 | 0.591208 | 0.131202 | 0.188329 | 0.3315 | 0.0901 | 0.3805 | 28.20867 |
| **Median** | 0.00000 | 0.000000 | 0.000000 | 4.987800 | 0.801989 | 336.5300 | 0.000000 | 0.039574 | 0.000000 | 0.0000 | 0.0000 | 0.3871 | 24.28000 |
| **Maximum** | 1.00000 | 1.000000 | 1.000000 | 7.348022 | 32.39000 | 4313.780 | 2.614400 | 1.158263 | 1.000000 | 2.1890 | 1.0000 | 0.8582 | 72.15000 |
| **Minimum** | 0.00000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 74.74000 | 0.000000 | 0.003782 | 0.000000 | 0.0000 | 0.0000 | 0.0000 | 7.850000 |
| **Std. Dev.** | 0.41490 | 0.114549 | 0.234726 | 2.249577 | 1.684468 | 1102.551 | 0.975284 | 0.225726 | 0.391494 | 0.6262 | 0.2868 | 0.2919 | 14.37491 |
| **Skewness** | 1.35073 | 8.509609 | 3.768068 | -0.987534 | 17.32081 | 1.640095 | 1.146032 | 3.289980 | 1.594329 | 1.5573 | 2.8613 | -0.0573 | 0.828124 |
| **Kurtosis** | 2.82448 | 73.41344 | 15.19834 | 2.606363 | 323.6766 | 4.445348 | 2.477683 | 13.79758 | 3.541885 | 3.8439 | 9.1873 | 1.4611 | 2.624816 |
| **Jarque-Bera** | 115.122 | 82432.72 | 3229.519 | 63.71054 | 1634193. | 201.8313 | 86.81011 | 2511.503 | 164.3277 | 163.57 | 1115.8 | 37.406 | 45.30164 |
| **Probability** | 0.00000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.0000 | 0.0000 | 0.0000 | 0.000000 |
| **Sum** | 83.0000 | 5.000000 | 22.00000 | 1572.291 | 357.8336 | 337202.7 | 222.8854 | 49.46315 | 71.00000 | 124.97 | 34.000 | 143.46 | 10634.67 |
| **Sum Sq. Dev.** | 64.7267 | 4.933687 | 20.71618 | 1902.784 | 1066.874 | 4.57E+08 | 357.6435 | 19.15796 | 57.62865 | 147.45 | 30.933 | 32.050 | 77695.90 |
| **Observations** | 377 | 377 | 377 | 377 | 377 | 377 | 377 | 377 | 377 | 377 | 377 | 377 | 377 |

## Appendix 7: Descriptive Statistics - Generation Plant Utilization

| | COMPFMKT | CONCESS | DIVEST | FRI | GREENFIELD | IRI | MGMTLEASE | INDOUTGDP | PLANTUTILIZ | URBANIS |
|---|---|---|---|---|---|---|---|---|---|---|
| **Mean** | 0.219577 | 0.013228 | 0.058201 | 0.514239 | 0.187831 | 0.312748 | 0.092593 | 27.25021 | 0.416568 | 34.68071 |
| **Median** | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 24.28000 | 0.420679 | 33.34500 |
| **Maximum** | 1.000000 | 1.000000 | 1.000000 | 2.614400 | 1.000000 | 2.189000 | 1.000000 | 72.15000 | 0.785293 | 83.80000 |
| **Minimum** | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| **Std. Dev.** | 0.414509 | 0.114399 | 0.234434 | 0.929544 | 0.391095 | 0.620503 | 0.290245 | 15.49082 | 0.148386 | 19.64369 |
| **Skewness** | 1.354833 | 8.521350 | 3.774072 | 1.367231 | 1.598504 | 1.660420 | 2.811057 | 0.564658 | -0.623102 | 0.287109 |
| **Kurtosis** | 2.835573 | 73.61340 | 15.24362 | 3.060003 | 3.555214 | 4.147353 | 8.902041 | 2.580437 | 4.383251 | 2.542024 |
| | | | | | | | | | | |
| **Jarque-Bera** | 116.0669 | 83108.13 | 3258.369 | 117.8239 | 165.8336 | 194.4243 | 1046.465 | 22.85939 | 54.59593 | 8.496612 |
| **Probability** | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000011 | 0.000000 | 0.014288 |
| | | | | | | | | | | |
| **Sum** | 83.00000 | 5.000000 | 22.00000 | 194.3823 | 71.00000 | 118.2186 | 35.00000 | 10300.58 | 157.4626 | 13109.31 |
| **Sum Sq. Dev.** | 64.77513 | 4.933862 | 20.71958 | 325.7477 | 57.66402 | 145.1541 | 31.75926 | 90466.96 | 8.300990 | 145474.8 |
| | | | | | | | | | | |
| **Observations** | 378 | 378 | 378 | 378 | 378 | 378 | 378 | 378 | 378 | 378 |

## Appendix 8: Descriptive Statistics - Per Capita Generation Energy Output

| | COMPFMKT | CONCESS | ELECTLAW | FRI | GREENFIELD | IRI | MGMTLEASE | GENOUTPUT | EXPIMP | RGDPPC |
|---|---|---|---|---|---|---|---|---|---|---|
| **Mean** | 0.230556 | 0.013889 | 0.269444 | 0.553196 | 0.197222 | 0.337586 | 0.097222 | 469.7672 | 0.908807 | 830.5123 |
| **Median** | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 115.8250 | 0.703837 | 330.5950 |
| **Maximum** | 1.000000 | 1.000000 | 1.000000 | 2.614400 | 1.000000 | 2.189000 | 1.000000 | 4778.500 | 32.39000 | 4313.780 |
| **Minimum** | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 11.21896 | 0.000000 | 0.000000 |
| **Std. Dev.** | 0.421775 | 0.117193 | 0.444289 | 0.961484 | 0.398455 | 0.631788 | 0.296672 | 843.1973 | 1.735481 | 1116.730 |
| **Skewness** | 1.279448 | 8.307472 | 1.039308 | 1.270927 | 1.521873 | 1.532797 | 2.719082 | 3.367428 | 16.65117 | 1.769826 |
| **Kurtosis** | 2.636988 | 70.01408 | 2.080161 | 2.789133 | 3.316097 | 3.765337 | 8.393407 | 14.51457 | 302.4574 | 4.791201 |
| | | | | | | | | | | |
| **Jarque-Bera** | 100.1960 | 71504.16 | 77.50123 | 97.58237 | 140.4646 | 149.7541 | 879.9369 | 2669.155 | 1361757. | 236.0630 |
| **Probability** | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | |
| **Sum** | 83.00000 | 5.000000 | 97.00000 | 199.1505 | 71.00000 | 121.5310 | 35.00000 | 169116.2 | 327.1706 | 298984.4 |
| **Sum Sq. Dev.** | 63.86389 | 4.930556 | 70.86389 | 331.8778 | 56.99722 | 143.2972 | 31.59722 | 2.55E+08 | 1081.270 | 4.48E+08 |
| | | | | | | | | | | |
| **Observations** | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 |

## Appendix 9: Descriptive Statistics - Transmission System Loss.

| | COMPFMKT | CONCESS | DIVEST | FRI | GREEN FIELD | IRI | MGMT LEASE | TRANSM LOSS | INDOUT GDP | POLCON | RPOPDENS | URBANIS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mean** | 0.210526 | 0.070175 | 0.064327 | 0.621721 | 0.239766 | 0.376364 | 0.064327 | 0.058623 | 29.43772 | 0.339008 | 276.6077 | 40.25629 |
| **Median** | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.055339 | 24.93500 | 0.320071 | 221.3650 | 39.55500 |
| **Maximum** | 1.000000 | 1.000000 | 1.000000 | 2.700000 | 1.000000 | 2.380600 | 1.000000 | 0.171273 | 73.49000 | 1.000000 | 1267.680 | 83.67000 |
| **Minimum** | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.004000 | 7.850000 | 0.000000 | 69.19000 | 0.000000 |
| **Std. Dev.** | 0.408280 | 0.255817 | 0.245695 | 0.995582 | 0.427566 | 0.685062 | 0.245695 | 0.028009 | 14.44252 | 0.313250 | 179.3823 | 17.59279 |
| **Skewness** | 1.420094 | 3.365334 | 3.551648 | 1.052939 | 1.219064 | 1.487350 | 3.551648 | 0.895170 | 0.735332 | 0.146319 | 1.324305 | 0.101597 |
| **Kurtosis** | 3.016667 | 12.32547 | 13.61420 | 2.234757 | 2.486116 | 3.677497 | 13.61420 | 3.797985 | 2.524021 | 1.349884 | 5.175497 | 2.729809 |
| **Jarque-Bera** | 114.9540 | 1884.795 | 2324.434 | 71.53951 | 88.47172 | 132.6367 | 2324.434 | 54.74990 | 34.04910 | 40.02140 | 167.4079 | 1.628647 |
| **Probability** | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.442939 |
| **Sum** | 72.00000 | 24.00000 | 22.00000 | 212.6286 | 82.00000 | 128.7166 | 22.00000 | 20.04921 | 10067.70 | 115.9407 | 94599.83 | 13767.65 |
| **Sum Sq. Dev.** | 56.84211 | 22.31579 | 20.58480 | 337.9933 | 62.33918 | 160.0347 | 20.58480 | 0.267509 | 71127.97 | 33.46088 | 10972703 | 105541.6 |
| **Observations** | 342 | 342 | 342 | 342 | 342 | 342 | 342 | 342 | 342 | 342 | 342 | 342 |

## Appendix 10: Descriptive Statistics - Distribution System Loss

| | COMPFMKT | CONCESS | DISTRIBLOSS | DIVEST | FRI | GREENFIELD | IRI | MGMTLEASE | RPOPDENS | URBANIS |
|---|---|---|---|---|---|---|---|---|---|---|
| **Mean** | 0.210526 | 0.070175 | 0.086051 | 0.064327 | 0.585116 | 0.239766 | 0.387026 | 0.064327 | 272.2415 | 40.23237 |
| **Median** | 0.000000 | 0.000000 | 0.069549 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 220.3950 | 39.60000 |
| **Maximum** | 1.000000 | 1.000000 | 0.600000 | 1.000000 | 2.614400 | 1.000000 | 2.380600 | 1.000000 | 729.0900 | 83.67000 |
| **Minimum** | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 69.19000 | 0.000000 |
| **Std. Dev.** | 0.408280 | 0.255817 | 0.065013 | 0.245695 | 0.984094 | 0.427566 | 0.695020 | 0.245695 | 169.6189 | 17.54069 |
| **Skewness** | 1.420094 | 3.365334 | 4.463408 | 3.551648 | 1.159852 | 1.219064 | 1.460857 | 3.551648 | 1.011693 | 0.074119 |
| **Kurtosis** | 3.016667 | 12.32547 | 28.03085 | 13.61420 | 2.467217 | 2.486116 | 3.605360 | 13.61420 | 3.031369 | 2.708564 |
| **Jarque-Bera** | 114.9540 | 1884.795 | 10063.80 | 2324.434 | 80.72454 | 88.47172 | 126.8660 | 2324.434 | 58.35476 | 1.523454 |
| **Probability** | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.466859 |
| **Sum** | 72.00000 | 24.00000 | 29.42940 | 22.00000 | 200.1096 | 82.00000 | 132.3628 | 22.00000 | 93106.61 | 13759.47 |
| **Sum Sq. Dev.** | 56.84211 | 22.31579 | 1.441294 | 20.58480 | 330.2386 | 62.33918 | 164.7212 | 20.58480 | 9810760. | 104917.4 |
| **Observations** | 342 | 342 | 342 | 342 | 342 | 342 | 342 | 342 | 342 | 342 |

## Appendix 11: Steps in conducting Principal Component Analysis for Regulatory Framework Index Calculation.

This appendix highlights the key steps in conducting the Principal Component Analysis (PCA) to determine the weights for the variables, for the formal and informal regulatory indices. PCA is basically a variable reduction technique which is used to reduce the observed variables which may be correlated and therefore redundant*, into a smaller number of principal components, which account for most of the variance in the observed data or variables.* Redundant variables in this case imply that the variables in question are correlated with one another, and therefore possibly measuring the same construct. In PCA, each component accounts for a maximal amount of variance in the observed variables which was not accounted for by the preceding components, and is uncorrelated or orthogonal, with all of the preceding components.[77]

Each principal component in the completed analysis, is therefore a different linear combination of the original variables and that each component is statistically orthogonal to the others[78]. *It is this latter property which lends the property of low multicollinearity in the final variables.*

### STEP 1: Component extraction

In Principal Component Analysis (PCA), the number of components extracted, equals the number of variables analysed. So in the case of *the regulatory framework index, since the number of variables being analyzed is 7, the number of components to be extracted will be 7. (See table 4.5 in the text).*

In PCA, one is extracting factors that account for less and less variance, thus guaranteeing minimal information loss. The first principal component is expected to account for a large amount of total variance, with each succeeding components, accounting for a progressively smaller amount of variance. PCA thus seeks the linear combination of the original variables, such that the derived variables capture

**77** For instance, the second principal component will account for a maximal amount of variance in the dataset, which was unaccounted for by the first component. In addition, the second component is uncorrelated or orthogonal with the first component.

**78** The components are therefore extracted with the restriction that they are orthogonal, and therefore display varying degrees of correlation with the original variables.

*maximum variance.* In other words, one wishes to extract from a set of '*m'* variables, a reduced set of '*n'* principal components that accounts for *most of the variance* in the '*m'* variables.

**STEP 1b: Eigenvalue and the variance question:**

The second column of tables 4.5 and 4.9 in the text, provides the eignevalues for computing the formal and informal regulatory indices respectively. The eigenvalues presented in the tables represent **"Eigenvalues of the Correlation Matrix",** and therefore represent the variance which is accounted for by a given component. *In that regard, each eigenvalue represent the amount of variance captured by one component.*

To compute the Eigenvalue, one starts with the correlation matrix, where the variances of all the variables are equal to 1.0. For the thesis, since we have *7 variables* for the formal regulatory index each with a variance of 1, the total variability that can be extracted is *equal to 7 times 1.* Similarly, for the informal regulatory index, since there are *5 variables,* the total variability which can potentially be extracted is *5 times 1.*

The results of the eigenvalues are presented in the second column of tables 4.5 and 4.9, and they show the variance of the factors which are successively extracted. In column 3, these values have been expressed as a percentage of total variance under the heading *"variance proportion".* The last column in tables 4.5 and 4.9 contain the cumulative variance extracted, under the heading *"Cumulative Proportion (%)".*

The variance proportion accounted for is calculated as:

Eigenvalue for the component of Interest ÷ Total eigenvalue of the correlation matrix.

For example:

From table 4.5, Principal component 1,

The eigenvalue = 5.5166

Total eigenvalue of correlation matrix = number of variables being analyzed = 7. 000 (since each variable contributes one unit of variance to the analysis).

The variance proportion is then computed as: 5.5166 ÷ 7.000 = 78.81%.

Similarly, for principal component 2 in table 4.5, the variance proportion is computed as:
0.7983 ÷ 7.000 = 11.40%

This method has been used to compute the *variance proportion (%)* in column 3, for tables 4.5 and 4.9 in the text.

**STEP 2: Which "meaningful" components to retain for analysis.**

From step 1, it is now clear that the number of principal components extracted equals the number of variables or factors being analysed. In step 2, the critical question is ***"which components are meaningful and should be retained for further analysis?"*** This question is resolved by using the *Kaiser Criterion (Kaiser 1960),* also known as the *Eigen-one criterion.* The rationale for this rule is that since each variable is expected to contribute *one unit* of the variance to the total variance[79], any principal component which possess an eigenvalue greater than 1.00 is therefore accounting for a greater amount of variance and is worthy of being retained. In other words, any variable which cannot extract as much as the equivalent of one variable, is accounting for less variance than has been contributed by one variable, and is therefore dropped and not used for further analysis.

Based on the Kaiser Criterion, the first principal component in tables 4.5 and 4.9 with eigenvalues of ***5.5166 and 3.0577,*** are retained and used to derive the eigenvectors and hence the weights in tables 4.6 and 4.10.

[79] In PCA, each variable is transformed such that it has a **zero mean and a variance of one.** Because of this, each observed variable is expected to contribute one unit of variance to the total variance in the data set. Therefore, the total variance will always be equal to the number of observed variables being analysed.

**STEP 3: Eigenvector (i.e. Factor Loading or Weights)**

The eigenvectors are the weights produced from the eigen equations, such that for a given set of data, *there are no set of weights which are capable of producing a set of components, which are more successful in accounting for the variance in the observed variables or the data set.* The eigenvector or loadings are computed[80] and reported for each variable for the first principal component, and are used as the weights to derive the formal and informal regulatory indices in tables 4.6 and 4.10 in the text.

[80] If an eigenvalue is known, its eigenvector can be computed. The reverse process is also possible; i.e., given an eigenvector, its corresponding eigenvalue can be calculated (Garcia 2006). See more details in Garcia, E. (2006), "Matrix Tutorial: Eigenvalues and eigenvectors", Mi Islita.com