ENERGY DEMAND IN GHANA: A CASE STUDY OF THE ELECTRICITY SUB-SECTOR

BY

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DECLARATION

This is to certify that this thesis is the result of research undertaken by ADOM, PHILIP KOFI towards the award of the Master of Philosophy in Economics in the Department of Economics, University of Ghana.

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ABSTRACT

In spite of the policy relevance associated with identifying the factors that affect electricity demand and quantifying their effects, there is still a dearth of research analysing aggregate electricity demand in developing countries. Even with the few studies that exist in the literature, the focal countries have been in Asia and the Middle East leaving a gap for Sub-Saharan Africa and Ghana in particular. In Ghana, efforts have been made (see Constantine et al, 1999 & Buskirk et al, 2006) to fill this gap. However, the focus of these studies has been on the household sector. The main focus of this work is, therefore, to forecast domestic electricity consumption specifically identifying what factors affect aggregate domestic consumption and assessing their impact using the ARDL Bounds Cointegration from 1975 to 2008. Also using data on Ghana I test the energy (electricity) conservation hypothesis using the Toda and Yomamoto Granger Causality test. The Bounds cointegration test shows evidence of a long-run equilibrium relationship implying that real per capita GDP, industrial efficiency, structural changes, and degree of urbanisation can be treated as the "long-run forcing variables" explaining total domestic electricity consumption. In the long-run, real per capita GDP, industrial efficiency, degree of urbanisation, and structural changes in the economy were found to be the main determinants of aggregate domestic electricity demand in Ghana while in the short-run all factors with the exception of structural changes in the economy were found to significantly impact on electricity demand. Aggregate domestic electricity demand is predicted to increase from 7,324 GWh in 2009 to 21,974 GWh in 2019 which represents an annual average growth rate of 11.8 percent. Based on the projected growth in electricity consumption, the total required plant capacity increase is projected to be 1,419 MW which represents an increase of 60% above the 2010 figure. This result implies that thermal

generation as a percentage of total installed capacity is predicted to increase from the current 40% to 58% by 2019. Also I found evidence in support of the energy (electricity) conservation hypothesis for Ghana. The result shows that only industrial efficiency drives electricity consumption downwards. Based on this I suggest the development and intensification of the country's energy efficiency programs. Specifically proprietary electricity efficiency technologies and processes that have significant electricity-savings potential should be identified systematically. Also options should be provided to facilitate the deployment of such technologies in the industrial sector.

DEDICATION

I dedicate this piece of work to my mum, Elizabeth Adutwumwaa, my sister, Joyce Adom, and my nephew, Prince Barns. Also I dedicate this work to the following friends; Doreen Lartey, John Kofi Nartey, Benjamin Odjidja, Vincent Mawuli, Jenita Sarpong, Prince Atsiano and Yobe Kombat Emmanuel for their enormous support.

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LIST OF ABBREVIATIONS

UNDP	United Nations Development Programme
TAPCO	Takoradi Power Company Limited
TICO	Takoradi International Company
EC	Energy Commission
VALCO	Volta Aluminium Company
PSEC	Power Systems Energy Consulting
GRIDCo	Ghana Grid Company
VRA	Volta River Authority
ECG	Electricity Company of Ghana
MW	Megawatts
KWh	Kilowatts hour
GWH	Gigawatts hour
PWD	Public Works Department
NED	Northern Electricity Department
IEA	International Energy Commission
GSS	Ghana Statistical Services
ISSER	Institute of Social Science and Economic Research
WAGPP	West Africa Gas Pipeline Project

WAPP	West African Power Pool
TT1PP	Tema Thermal one Power Project
TT2PP	Tema Thermal two Power Project
MOU	Memorandum of Understanding
PURPA	Public Utilities Regulatory Policies Act
BSP	Bulk Supply Points
KV	Kilovolts
PURC	Public Utility Regulation Commission
GDP	Gross Domestic Product
DBT	Decreasing Block Tariff
IBT	Increasing Block Tariff
BST	Bulk Supply Tariff
TSC	Transmission Service Charge
DSC	Distribution Service Charge
EUT	End-User Tariff
ETU	Electricity Transmission Utility
PF	Productivity Factor
QSP	Quality of Service Penalty
CCAP	Cost of Capital Adjustment Factor

AAF	Adjustment Formula
ECOWAS	Economic Community of West Africa States
SAPP	Suon-Asogoli Power Plant
BPP	Bui Power Plant
VOLL	Value of Lost-Load
EBSST	Electricity Basic Services Support Tariff
GCC	Corporation Council for Arab States of the Gulf
TTEB	Typical Electricity Bill
TOD	Time of Day
ADI	Africa Development Indicators
IFS	International Financial Statistic

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CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

"Energy is the indispensable force driving all economic activities" (Alam, 2006). It has been regarded by many as being central to any discussion on sustainable development. Thus, there is some sort of causational effect of energy services on all of the three pillars of sustainable development: economic, social and environmental (Najam et al. 2003, Covallaro, 2005, and UNDP, 2000). In terms of the economic facet of sustainable development, energy plays a crucial role in the development of businesses. Also in terms of the environmental aspects, conventional energy carriers, for example, are major sources of environmental stress both at global and the local level. Thus, a switch towards a more efficient and cleaner form of technology provides a great relief to environmental contamination. Lastly, in terms of the social dimension, energy is a prerequisite for the fulfilment of many basic human needs and services (Najam et al. 2003).

Electricity is a key infrastructural element for economic growth. It is a multitalented "energy currency" that underpins a wide range of products and services that improve the quality of life, increase worker productivity and encourage entrepreneurial activity.[1] Individuals need electricity for lighting, cooking, heating, melting, and cooling, just to mention a few. Also industries use electricity as an input in their production process and to be a foil for the services of labour and capital. In

[1] Like water, electricity as a commodity has evolved as a basic necessity of life. It is the food we eat, the water we drink, the air that refreshes us, the music we listen, the cloth we wear and the blood that flows in the industrial veins of economies. (Author's citation)

Ghana, electricity is a key input in the production of goods and services. It is a foremost input component for several sectors, including manufacturing, communication, education, commercial, health, entertainment and construction.

In spite of the decisive role that electricity plays in the socio-economic development of economies, the performances of the power sector in most African countries have been abysmal (Gutierrez, 1995). Among the factors alluded to are managerial inefficiency, importunate government interference in daily operations, investment and pricing decisions, opaque regulatory systems, and lack of capital to invest in rehabilitation and expansion of the power system. In Ghana, many factors bedevil the efficient operations of the electricity sub sector. These include among other things recurrent major breakdowns arising from the use of out-dated and heavily loaded equipments, lack of adroitness between the town planning unit and electricity company of Ghana ensuing in poor overall power system planning and over loading of equipments, derisory generation due to operational/technical problems arising from machine breakdown and low water levels, and high indebtedness to ECG by both public and private consumers who are disinclined to pay for electricity consumed as and when it is due.

Of most significant of these problems is the existing gap between demand for and supply of electricity in the country. Currently, the electricity sector in Ghana is characterised by chronic power shortages and poor power quality. Moreover, the poor financial state of the current electricity sector has resulted in inadequate investment in additional generational capacity, which is more likely to exacerbate the existing gap between demand for and supply of electricity. This has serious ramifications on the stability of the economy. Clearly, there is a large role and potential for demand side management (DSM) programmes.

1.2 Statement of the Research Problem

Electricity offers the possibility for pumping, purifying, boiling, disinfecting, storing and distributing water (IEA, 2002). It helps provide drinking water both for domestic and irrigation purposes. In terms of health care delivery, reliable access to electricity is a precondition for an improved and convenient health care.

Despite the immense importance of electricity towards the development of the economy, electricity production in Ghana has been very inconsistent largely due to its nature dependence and inadequate investment into additional capital. For instance, between the periods 2001-2005 and 2006-2007 while total electricity production decreased by 13.2% and 16.4% respectively, largely as a result of the fall in the water level of Akosombo, the major power house, electricity production increased by 7.6% between 2008 and 2009 (GSS, 2001-2005; ISSER, 2007-2009).

Converse to these trends in electricity production, domestic consumption of electricity continues to increase at an annual estimated rate of 14%. For example, during the periods 2000-2001, 2003-2006, and 2007-2008 domestic consumption of electricity increased by 7%, 33.4% and 12.12% respectively. However, domestic consumption of electricity decreased by 20% between 2002 and 2003 which was largely due to decrease in VALCO's load (Energy Commission, 2008).

To make up for the demand-supply gap, there have been several efforts by various governments via the initiation and implementation of different programmes and projects such as Takoradi thermal plant, Takoradi International company (TICO), installation of 126 MW and 80 MW thermal palnts at Tema, installation of 126 MW Tema thermal 1 Power Project (TT1PP), installation of 49.5 MW Tema thermal 2 Power Project (TT2PP), West Africa Gas Pipeline Project (WAGPP) and West African Power Pool (WAPP). However, the incessant growth in domestic electricity consumption has made it exigent for the various supply efforts made by various governments to unreservedly contend with the problem of power shortages experienced in the electricity sub-sector in Ghana.

Demand and supply elasticities over the years have been used to elicit consumer and producer responsiveness in the market. Obtaining these elasticities require that we consider demand and supply equations within a competitive market framework where there are so many buyers and sellers, perfect knowledge, free entry and exit and homogeneity of products. In a market where government require supply monopoly, supply equations will not be meaningful. Alternatively, where there exists monopsony power in the market, demand equations will not be meaningful (see Carol Dahl, 2006). The market for the supply of electric power in Ghana has long been single dominated. Even with the enactment of the EC Act, 1997, Act 541 which is to infuse competition into the electricity sector, the Volta River Authority at present contributes 88 percent of all grid-connected generation with only 12 percent of generation coming from independent private producers. As at 2010, only five private entities had announcement or were at various stages of construction of a total of 960 MW of new generation facilities. The monopolistic feature of the electricity supply market in Ghana therefore makes it inappropriate to estimate a supply equation. However, the market for the demand for electricity is competitive with many consumers consuming homogeneous product. That is each kilowatt hour of electricity consumed is like any other. Moreover, consumers can freely enter (although a reconnection fee is require) and exit.

It is against this background that this thesis seeks to estimate aggregate domestic electricity demand based on an Autoregressive distributed lag (ARDL) model (Pesaran et al, 2001), identifying the factors responsible for the growth in aggregate domestic electricity demand both in the short-run and long-run periods. This is useful for the formulation of appropriate electricity pricing policies, demand-side management programmes, determining appropriate investment requirements based on demand forecasts.

1.3 Research Questions

1. What factors underlie the historical growth trends in electricity demand in Ghana both in the short-run and long-run periods?
2. Is electricity conservation a viable option for Ghana?
3. What is the required plant capacity increase in the power sector?

1.4 Objectives of the Study

The general objective of this study is to estimate future aggregate domestic electricity demand for Ghana. Specifically this thesis seeks to:

1. Identify the factors that underlie the historical growth trends in aggregate domestic electricity consumption both in the short-run and long-run.
2. Determine whether electricity conservation is a viable option for Ghana.
3. Determine the required future plant capacity increase for the electricity sector.

1.5 Justification for the Study

Obtaining forecasts based on extrapolation methods as adopted by VRA and GRIDCo although good for short-term forecasting, is not suitable for long-run forecasting. These extrapolation methods have been criticised on the grounds that these methods do not provide any scope to internalise the changes in factors such as the role of incomes, prices, population, urbanisation and policy changes. Given the fact that electricity as a commodity is affected by a lot of countervailing factors in the long-run, using extrapolation methods that uses the defined patterns in series to predict series could result in either overestimation or underestimation with the attendant effect of possible endorsement of plants that may not be needed for several years and localised blackouts or brownouts. This thesis therefore, proposes a conditional forecasting based on econometric technique which internalises changes in factors such as income, urbanisation, structural changes in the economy and industrial efficiency.

The widely used approach to energy demand modelling, 'energy approach' has been criticised as been inappropriate when analysing demand for specific energy type (Baxter and Rees, 1968). This is due to the varying conversion efficiencies of different energy type depending on their application and the wide ranges of substitutability between the different energy types in their various applications. The most appropriate approach as argued by Baxter and Rees (1968) is to treat each energy type as a separate energy input entering into the production function of firms and households. This thesis thus, models aggregate electricity demand based on a firm/household production model that treats electricity as a separate energy type that enters into the firm's/household's production function.

Literature on the causal relationship between energy (electricity) consumption and economic growth is very scanty for Ghana. Even with the few that exist, results have been mixed (see; Lee, 2005; Wolde-Rufael; Twerefo et al 2008; and Akinlo, 2008). This thesis will therefore be an addition to studies in the literature.

Identifying the factors that affect electricity demand and quantifying their effects has important implications for demand-side management programmes. In spite of this there is still a dearth of research analysing aggregate domestic demand for electricity in developing countries. Even with the few that exist in the literature, the focal countries have been in the Asia and Middle East leaving a gap for sub-Saharan Africa and Ghana in particular. In Ghana efforts have been made to fill this gap (see; Constantine et al 1999; and Buskirk et al, 2006) but these studies focused on household demand for electricity. This thesis will however, draw from recent developments in energy demand modelling to estimate aggregate domestic electricity demand.

Lastly, with the ongoing reform process, with associated unbundling of electricity supply services, tariff reforms and rising role of the private sector, a realistic assessment of demand assumes ever-growing importance. These are required not merely for ensuring optimal phasing of investments, a long term consideration, but also rationalising pricing structures, assessing system security, scheduling of generating utilities and designing appropriate demand side management programs, which are in the nature of short or medium term needs.

1.6 Hypothesis Testing

This study specifically seeks to test two hypothesises;

Hypothesis one*: real per capita GDP, urbanisation, industrial efficiency and structural changes in the economy do not significantly affect electricity consumption.*

Hypothesis two*: electricity conservation is not a viable option for Ghana.*

1.7 Scope of the Study

The study seeks to estimate aggregate domestic electricity demand for Ghana. Specifically the study analyzes the potential effects of demographic, economic and industrial factors on the historical trends in aggregate domestic electricity consumption in the country. Time series data spanning from the period 1975 to 2008 would be collected on key macroeconomic variables including total domestic consumption of electricity, population growth and degree of urbanization, real per capita gross domestic product, industrial efficiency and structural changes in the economy. The selection of the explanatory variables is purely based on economic theory. Also time series data spanning from 1971 to 2008 were collected on electricity consumption and real per capita GDP to test the electricity conservation hepothesis for Ghana. The choice of the study periods 1975-2008 and 1971-2008 is purely based on data availability of the variables considered in each case.

1.8 Organization of the Study

The rest of the study is organized as follows: Chapter two provides an overview of the electricity sector in Ghana with special focus on the trends in demand for and supply of electricity, historical analysis of the electricity sector and major reforms in the electricity sector. Chapter three reviews both theoretical and empirical studies on the subject matter. Chapter four discusses the theoretical and empirical framework whiles chapter five will be concerned with the presentation and discussion of results. Chapter six concludes the paper and makes policy recommendations. In the chapter that follows an overview of the power sector in Ghana is provided.

CHAPTER TWO

OVERVIEW OF GHANA'S POWER SECTOR

2.0 Introduction

This section generally provides an overview of the electricity sub-sector. Specifically, this section provides a trend analysis of demand for and supply of electricity, import and export of electricity, pricing of electricity, deficit situation, losses in the electricity sector, economic cost of power outages, forecasted electricity demand and the structure of Ghana's electricity sector.

2.1 Overview of Energy Consumption

Primarily, Ghana's energy sector operates under the jurisdiction of the Ministry of Energy which oversees the operations of all other energy sectors. The ministry is charged with the responsibility of formulating and executing energy policies in Ghana. With regard to regulation, three different institutions have been charged with different mandates. The first of these institutions is the Energy Commission (EC) which has the mandate of promoting and ensuring uniform rules of practice for transmission, wholesale supply and distribution of electricity. The next regulatory institution is the Public Utility Regulatory Commission (PURC) which regulates bulk generation charge, transmission service charge, distribution service charge and the End-user tariffs and also provides electric utility services. The last of the regulatory institutions is the National Petroleum Authority which monitors the application of petroleum pricing formulae to ensure its full and timely implementation.

Basically, there are three main energy forms in Ghana: petroleum, biomass/wood fuel and electricity. Biomass forms the bulk of the country's energy consumption constituting about 60% of total national energy consumption with the remaining 40% contributed by petroleum and electricity. Growth of energy consumption after 2001 has been very sluggish in Ghana. In 2001, for instance, consumption of energy in Ghana grew by 34.2% with biomas, petroleum and electricity consumption growing by 35.5%, 0.1% and 7% respectively. In 2002, however, energy consumption in Ghana decreased tremendously from the 2001 34.2% increase to 4.1%. Within this same period, while petroleum and biomas consumption increased by 6.3% and 4.1% respectively, electricity consumption decreased by 2.5%. In 2008, while energy consumption grew by only 0.7%, thus 0.4% higher than the previous year's growth, electricity and biomass consumption grew by 12% and 0.86% respectively with petroleum consumption experiencing a decrease of 2.6%. Between 2000 and 2008 the growth rate of petroleum, biomas and electricity consumption averaged at 2.86%, 5.99% and 1.73% respectively. Figure 2.1 below depicts the shares of petroleum, biomas and electricity consumption in total energy consumption. From figure 2.1, it is obvious that biomas consumption constitutes the highest share averaging about 76.26% in total energy consumption between 2000 and 2008. This is followed by petroleum consumption with an average share of 17.23% and electricity consumption with an average share of 6.51% within the same period. This implies that in Ghana biomas is the dominant energy type for households followed by petroleum and electricity. The current energy structure has serious implications on climate warming (carbon dioxide emissions), the environment (deforestation) and the health of individuals (respiratory effects from smokes). The current structure justifies the need to develop renewable forms of energy (biofuel and solar) and cleaner forms of energy (wind) in Ghana.

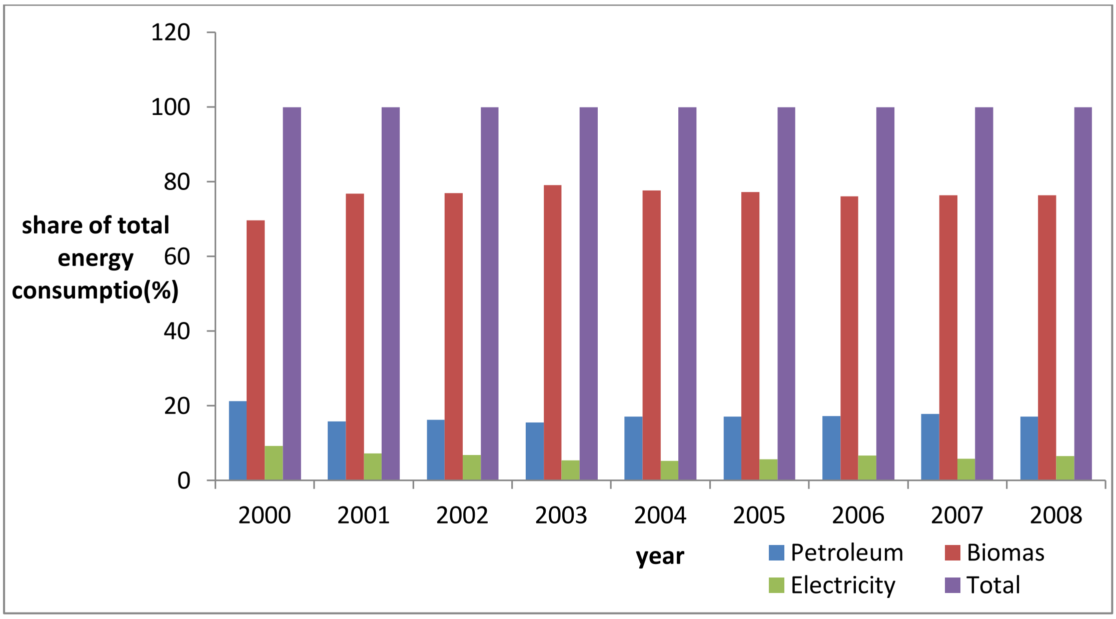

Figure 2.1: Share of Energy Type in Total Energy Consumption (%)

Source: Energy statistics; Energy Commission, Ghana

2.2 Overview of the Electricity Sub-Sector and Growth

Electricity generally passes through three-step phases before getting to the final user. First, power is produced from generators which are located far from the load centres. Power is then transferred to the transmission grid, which comprises transmission lines, transformers, and other components, to the bulk load distribution substations. From the bulk load distribution substations power is delivered to the individual customer sites using distribution lines.

In Ghana, these three-step processes are controlled by three different utility companies. The Volta River Authority (VRA), which is a state-owned enterprise, is solely responsible for bulk power generation in the country. Currently VRA operates the Akosombo and Kpong hydro stations which happen to be the major power generation sources in the country. Ghana Grid Company (GRIDCo) is responsible for transmitting power from bulk power plants to distribution lines while Electricity Company of Ghana (ECG) and Northern Electrical Department (NED), a subsidiary of VRA, are responsible for distributing power to the final consumer. ECG[2] serves the southern half of the country while NED supplies power to the northern part of the country.

The electricity sector has experienced significant growth over a decade now. In 1992, electricity and water sector recorded a growth rate of 12.02% which was 5.43% higher than the previous year. The primary reason, as reported in the budget statement and economic policy for 1993 of Ghana, included expansions in the national electricity grid under the rural electrification programme and the expansion and up-grading of some urban electricity distribution networks. In 2000, the sector witnessed a growth rate of 4.5% which is 0.93% below the growth rate achieved in 1992. In terms of the sectors relative contribution to total industrial growth in the country, the electricity sector contributed 10.21% of total industrial GDP in 2000. In 2005, the sector witnessed an increase in growth rate of 12.4% which translated into the sectors increased relative contribution to total industrial GDP of 11.9%.

However, in 2007, the sector recorded a decrease in growth rate of 17.4% which caused the sector's relative contribution to total industrial GDP to fall to 10.2%.[3] The major reason behind the sectors decreased contribution was mainly due to the serious drought that thumped the Ghanaian economy in 2007 which led to plummet in the water level of Akosombo, the foremost power house for the country.

[2] ECG was responsible for distribution of power in all of Ghana up until 1987 when NED was established as a division of VRA with the responsibility of wholesale power distribution in the northern sector of Ghana.

[3] ISSER, State of the Ghanaian Economy

Table 2 below shows the relative contribution of industrial sub-sectors to total industrial GDP between 2000 and 2009.

Table 2: Relative Contribution of Industrial Sub-sectors to Total Industrial GDP

Real	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Industry (% GDP)	25.2	25.0	25.0	25.0	24.7	25.1	25.8	23.7	25.6	24.9
Mining&Quarrying	22.1	21.1	22.1	21.0	20.6	20.4	21.1	23.7	22.3	21.5
Manufacturing	36.4	36.7	36.4	36.6	36.5	35.6	33.9	31.0	29.8	29.9
Electricity&Water	10.2	10.3	10.2	10.2	10.1	10.5	11.9	9.5	10.2	10.3
Construction	31.3	31.9	31.3	32.3	32.8	33.5	33.1	35.7	37.6	38.3
Total	100	100	100	100	100	100	100	100	100	100

Source: Ghana Statistical Service/ MoFEP

2.2.1 Generation Resources in Ghana

Generation of electricity in Ghana is basically by the public sector. This has been the case since the pre-independence era when the Public Works Department (PWD) was in charge of electricity generation in few urban centres and mining towns. The Volta River Authority (VRA) was originally charged with the responsibilities of developing, generating, transmitting and distributing electricity power in Ghana. However, with the restructuring of the power sector, VRA is currently answerable to generation of electricity with the responsibilities of transmission and distribution been carried out by Ghana Grid Company limited (GRIDCo) and Electricity Company of Ghana (ECG) and Northern Electricity Department (NED) correspondingly.

Ghana currently relies on two primary types of generation facilities/resources; hydroelectric plants and thermal plants. Generally there are seven major generation facilities in Ghana; two hydroelectric plants and five thermal plants. The two hydroelectric plants which are located at Akosombo and Kpong on the Volta River represent the hub of Ghana's generation system accounting for about 60% of the national total. The Akosombo dam still remains the largest single generation facility in the country with an installed capacity of 1020 MW, which is more than 50% of total national installed capacity. The Kpong dam operates downstream of Akosombo and has an installed capacity of 160 MW. Ghana's five thermal plants: two located at Aboadze near Tarkoradi (TICO & TAPCO) and three located in Tema (TT1PP, TT2PP & MRP) account for the remaining 40% of generation capacity. The Aboadze thermal plants provide a total maximum capacity rating of 550 MW while the remaining three located in Tema provide an additional 213 MW of capacity (Akosombo Brochure, VRA, 2010). Figure 2.2 shows hydro and thermal generation from 2000 to 2008.

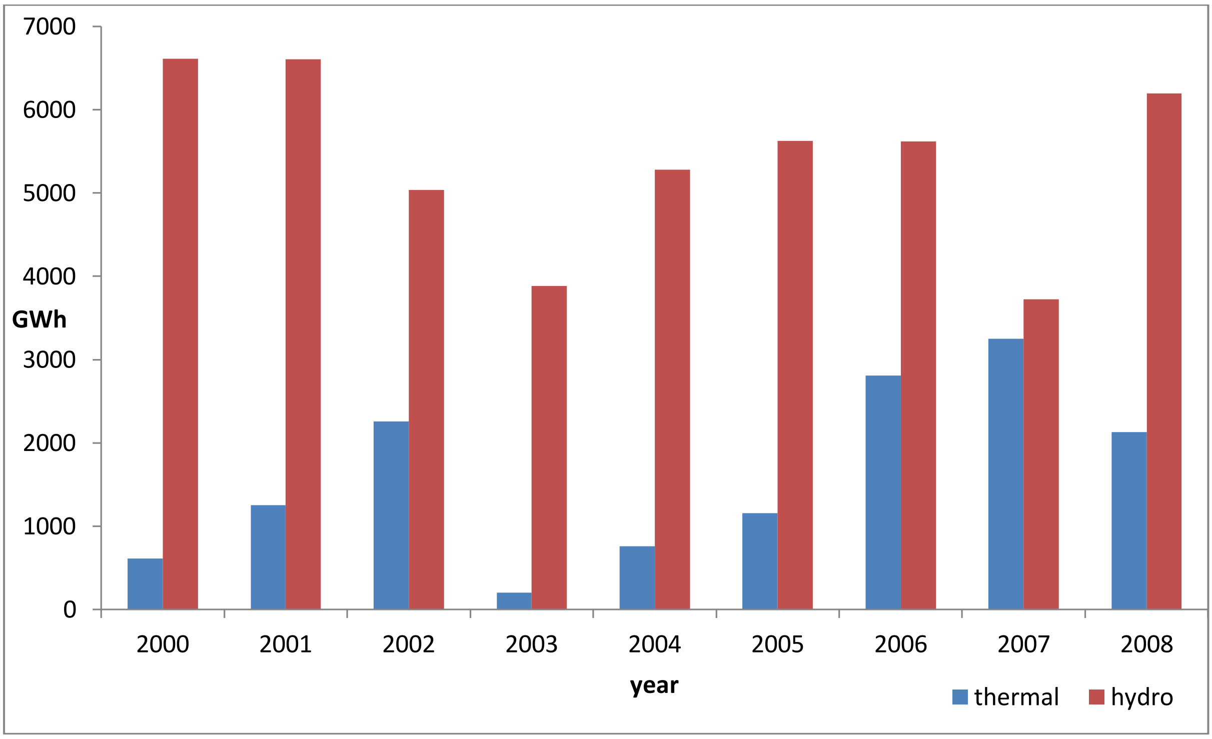

Figure 2.2: Hydro and thermal generation in Ghana

Source: Energy Statistic, Energy Commission, Ghana

From Figure 2.2, two things clearly stand out. The first is that, Ghana's electricity generation has been largely hydro dependent. The second is that there has been a declining reliance on hydro as the major source of power over the last decade. In other words, there has been a partial switch of generation source from hydro to thermal. This diversification of electric power generation was largely informed by power crisis that smack the country in the periods 1983, 1994, 1997/1998 and 2006/2007 due to the serious drought experienced resulting in a plunge in the water levels of the main hydro stations.

2.2.2 Structure of the Power Sector in Ghana

Utility operations have long been seen as natural monopolies because of the extensive economies of scale that exist in the industry[4]. As a consequence, most utility companies around the globe were structured as such with extensive amalgamation of generation, transmission and distribution services and centralized planning of supply resources to meet growth in demand. This integral structure was seen to enhance coordination and efficiency in the design, development and financing of wholesale power supply resources. Utility companies, as a measure to avoid exploiting consumers, were therefore regulated by government to charge a fixed rate of return above their cost.

However, with time, it became evident that state-owned and vertically integrated monopoly structure was beleaguered by poor performance and limited capital for operations and investment. For example, the state-owned power companies had high cost and untenable tariffs that under recovered the long-run marginal cost of their operations thereby weakening their balance sheets and making capital inaccessible. Furthermore, the lack of capital in the power industry led to underinvestment in utility infrastructure which led to higher operating costs due to expensive emergency maintenance and frequent and/or prolonged outages.

[4] Natural monopoly occurs in an industry where the capital cost is so high that it creates a barrier to other entrants, making it unprofitable for a second company to compete. This high cost creates economies of scale that make it more efficient to have one producer or supplier rather than several. Economies of scale refer to the benefits associated with large scale production.

The lack of competition inherent in the monopoly structure in large part accounted for the poor performance and poor managerial decisions. As an example, one of the main reasons behind power sector reform in Columbia was the high technical losses (theft and unaccounted consumption) in the system. More so managerial decisions at state-owned utility companies were heavily influenced by government objectives which were not necessarily consistent with the utility companies' objective. Given the impact that adjusting tariffs to ensure the full cost of power production and delivery will have on voters, it was always challenging for governments to adjust tariffs to reflect the full marginal cost. As a consequence the tariff charged to consumers lagged the full cost of production and delivery. These factors severely affected power supply reliability which in many countries retarded economic growth.

Thus, a structural shift from a fully regulated monopoly towards private participation was necessary to enhance competition. Technological advances in combined cycle technology challenged the long held economies of scale view and fuelled the migration to a new structure. Relatively new and small-sized combined cycles were more efficient than large-scale coal and oil/gas steam plants. Therefore, it was possible for investors to enter the utility business and invest in small and efficient combined cycle units to supply wholesale power.

Many countries including Ghana embarked on power sector reforms to migrate from the fully regulated monopoly structure towards a deregulated competitive market structure. In order to make competitive markets possible, it was necessary to open access to transmission lines to permit new market entrants to buy and sell power. Therefore, it was pertinent to functionally unbundle generation, transmission and distribution.

Ghana began her market-based power sector reforms in the mid-nineties to open up the industry to new market participants and simultaneously began to unbundle wholesale power generation and transmission. Before the reforms, Ghana's power market was highly regulated, with generation and transmission vertically integrated in VRA and distribution handled by ECG, a fully state-owned enterprise and NED, a subsidiary of VRA. ECG delivered power o the southern half of the country while NED delivered power to customers in the Northern half. As like many developing nations, Ghana needed outside capital to help develop her power sector. As part of the power sector reforms, Ghana commenced the process of unbundling generation, transmission and distribution functions into separate markets with immediate competition in generation and eventually distribution.[5]

Since then utility companies have become specialised entities focusing on one of the three areas. VRA maintains its generation assets including Akosombo, Kpong and Aboadze and now focuses almost utterly on generation. ECG and NED continue to focus on distribution. As a new public utility, GRIDCo, essentially spanned out of VRA in 2006, has the responsibility of operating transmission in an open and non-discriminatory manner.

Several pieces of legislations have been passed following the reform to facilitate the creation of competitive wholesale power market. Currently, there are two regulatory institutions; Energy Commission and Public Utility Regulatory Commission charged with the responsibility of creating and maintaining a healthy and competitive power sector. PURC sets rates and tariffs, monitors performance, promotes fair competition and works to balance the interest of utility providers. EC issues licenses and establishes performance standards for utility operators.

[5] Distribution has historically been functionally unbundled in Ghana.

Since the enactment of the EC Act, 1997, Act 541, five private entities have announced or are at various stages of construction of a total of 960 MW of new generation facilities (PSEC & GRIDCO Report, 2010). The influx of the new generation facilities could provide the redundancies needed in generation, which would significantly improve generation reliability or at least get the industry a lot closer to where it needs to be.[6]

Thus, a structural shift away from fully regulated monopoly towards competitive market structure with private participation has in part enabled the availability of physical redundancies in generation. However, there is still the need for government to provide additional economic incentives absent in existing agencies. While the reform process has formally been ended, the power sector is currently undergoing transition in terms of achieving the designed structure. At present, VRA accounts for 88% of all grid-connected generation with only 12% of generation coming from independent power producers. Since generation reliability must be combined with transmission reliability to ensure overall system reliability, effective strategies need to be put in place to ensure timely investment in transmission. Although, Ghana has witnessed private sector response to generation investment, transmission appears to be lagging since there is, currently, no mechanism in place for private sector participation in transmission investment.

2.2.3 Pricing of Electricity in Ghana

Price is an important determinant of demand for any commodity. The level of price at any point in time reflects or reveals different responses from consumers

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[6] PSEC and GRIDCo: Ghana Power Reliability Report, 2010
Some developing countries notably those in Asia, Africa and the Middle East featured state-owned vertically integrated legal monopolies, while others particularly in South America featured separate distribution and customer services from bulk power generation and transmission.

toward the demand for the commodity in question. Consumers of most products face a unique price by which their consumption decisions are guided and also can store the products. However, electricity as a commodity is unique from other commodities in two respects. First, electricity as a commodity cannot be stored. Thus, once it is produced, it must be consumed instantaneously. Secondly, consumers of electricity in contrast to other products they consume face a schedule of prices which guides their consumption decision. According to the literature, the typical tariff schemes for electricity pricing are three: (i) constant rates, (ii) increasing block rates and (iii) decreasing block rates. In the first case, users pay the same price irrespective of the quantity consumed in KWh. The second approach makes the consumer pay more for each additional KWh of electricity consumed, while in the third case consumers pay less as their consumption of electricity increases.

In Ghana the increasing block tariff (IBT) is practiced. The increasing block tariff serves as an incentive for small consumers of electricity and a disincentive to large consumers of electricity. However, the decreasing block tariff rates serves as an incentive for large consumers of electricity and a disincentive to small consumers of electricity.

Basically, there are four different tariffs; Bulk supply tariff (BST), Transmission service charge (TSC), Distribution service charge (DSC) and End-user tariff (EUT). BST represents the maximum charge approved by PURC for the procurement of capacity and energy at each Bulk Supply Points that distribution utility company shall be allowed to recover from customers through the End-User tariffs. The BST is derived as the weighted average of the purchase prices of capacity and energy. In short, it is the price of electricity at the Bulk Supply Points (BSP). Transmission service charges (TSC) are charges paid to the Electricity Transmission

Utility for the provision of transmission services. It is important to know that the BST is the sum of capacity and energy purchases from the wholesale power supplies and transmission charges.

Distribution service charges (DSC) are charges paid to the distribution utility companies to cover their cost of providing services to regulated customers. This is established based on the distribution added value computed from distribution utility companies. The DSC is adjusted annually taking into account average inflation, productivity factor (PF) set by PURC, Quality of Service Penalty/Reward (QSP) set by PURC and the Cost of Capital Adjustment Factor (CCAF) set by PURC. The End-User tariff (EUT) is the sum of the BST and DSC. EUT is the retail price charged to the end-user by distribution utility companies. EUT applies to all customer categories except the "lifeline" consumers.

"Lifeline" consumers refer to consumers of electricity with consumption capacity of below 50KWh. The basic rationale behind the "lifeline" consumer philosophy is that all people regardless of their economic status must have equal access to electricity since it is a necessity. Thus, low income people who cannot afford to pay the full cost of supplying electricity must not be deprived of it. As a result "lifeline" consumers are made to pay a low fixed rate commensurate with their means. The "lifeline" consumption level is determined by PURC bearing the following factors in mind, national minimum wage, ability to pay for rural consumers, the price of a gallon of kerosene and the average cost of hydro. Beneficiaries of the "lifeline" consumption rate are also determined by PURC.

The end-users serviced by the distribution companies are classified as residential, non-residential, SLT-LV, SLT-MV and SLT-HV.[7] The residential, non-residential and SLT-LV customers are supplied electricity at nominal voltage levels of 415/230V and are thus classified as Low Voltage (LV) consumers while SLT-MV and SLT-HV consumers are classified as Medium Voltage (MV) customers for the purposes of cost allocation.[8] The total expenses of the distribution utility company allocated to these classes of consumers are based on the actual costs incurred by the distribution companies in the delivery of service.

Electricity tariffs in Ghana have been generally low compared to the Sub-Saharan African average of US$ 0.13 per kilowatt-hour. Compared to West Africa, Ghana's electricity tariff is amongst the lowest. The main reason is that Ghana's electricity is mainly hydro-based. Hydro-electric power is characterised by high up front capital cost and extremely low marginal production costs. As a result, stakeholders in Ghana's power sector are used to extremely low electricity costs. Table 2.1 presents the end-user tariff for Ghana from 2000 to 2010.

[7] Regulated customers as defined by the Ghana Energy Commission are those customers whose annual consumption is less than 50GWh.
Non-Residential customers are regulated customers who use electricity for commercial and non-domestic activities, maintain a consumption level equal to or less than 100 kilo volt Ampere at a service voltage of 415 Volts and/or 240 Volts.
Residential customers are consumers who use electricity for non-commercial uses, maintain a consumption level equal to or less than 100 kilo volt Ampere at a nominal service voltage of 415 Volts for 3 phase and/or 240 volts for single phases.

[8] SLT-LV Customers are customers who are either supplied at a voltage level of 415 Volts and have a maximum demand above 100 kilo Volt Ampere or are supplied at 415 volts but have consumption less than 100 kilo volts Ampere.
SLT-MV Customers are consumers who are supplied at a voltage level exceeding 415 Volts but less than 11 kilo Volts and have maximum demand above 100 kilo Volts Ampere.
SLT-HV Customers are consumers who are supplied at a voltage level of 33 kilo Volts and have maximum demand of equal to or above 100 Kilo Volt Ampere.

Table 2.1: End-User tariff (GHp/KWh

Charges	2001	2002	2003	2004	2005	2006	2007	2008	2010
BST	1.94	3.59	4.27	4.25	4.25	4.94	6.11	6.11	14.31
DSC	1.96	2.64	2.92	3.15	3.15	4.5	5.85	5.85	9.88
EUT	3.9	6.23	7.19	7.4	7.4	9.44	11.96	11.96	24.19

Source: Public Utility Regulation Committee

From table 2.1, the end-user tariff increased from 2001 to 2002 by 59.7%. However, between 2004 -2005 and 2007-2008 the end-user tariff remained stable at GHp 7.4 and GHp 11.96 respectively. However, from 2008 to 2010 the en-user tariff increased by a percentage of 89.4%. This increase was meant to help utility companies cover their cost of production and also realise some profit. On the average, Ghana's end-user tariff stood at GHp 9.963 /KWh between 2000 and 2010.

2.2.4 Electricity Demand and Supply in Ghana

Electricity demand in Ghana is divided across 40 load centres, which includes cities, clusters of small towns and villages and large industrial sites such as mines. In Ghana, a relatively small number of load centres account for a large fraction of total electricity demand. Ghana's two largest load centres together accounts for nearly 68% of peak demand and 72% of electricity demand in 2009. Most of these load centres are found in the urban centres of Accra, Kumasi and Tema which account for approximately 49% of total national peak demand (Energy Statistics, Energy Commission). The remaining major load centres are associated with heavy industrial activity. The four largest mining companies alone account for 12.5% of national peak demand. For instance the load centres at Takoradi and New Obuasi had peak demands of 44.7 MW and 53 MW respectively while that of New Obuasi as a mining site had over 50% more annual energy demand than Takoradi.[9] Generally domestic consumption of electricity has been increasing continuously even though domestic production of electricity in Ghana has been very inconsistent largely due to inadequate investment in additional capital and unpredictable nature of the weather.

It is important to reiterate here that the balance between electricity demand[10] and supply is an important prerequisite to ensuring a reliable electricity system. Ghana's electricity sector has experienced considerable prolong power shortages over the last decade. For instance in 2000, while electricity demand stood at 7,488.9 GWh, electricity supply stood at 7,223 GWh representing a demand-supply gap of 265.9 GWh. Also in 2001, while domestic electricity demand stood at 8,012.1 GWh representing a 7.1 percent increase, domestic electricity supply stood at 7,859 GWh representing an increase of 8.8 percent. This shows a demand-supply gap of 153.1 GWh. However, in 2008 while domestic electricity demand stood at 8,066 GWh, domestic production of electric power stood at 8,324 GWh representing a demand-supply gap of -257.8 GWh. These trends are better displayed in figure 2.3 below.

[9] PSEC and GRIDCo: Ghana Power Reliability Report, 2010.

[10] Electricity demand=total domestic consumption+ system losses

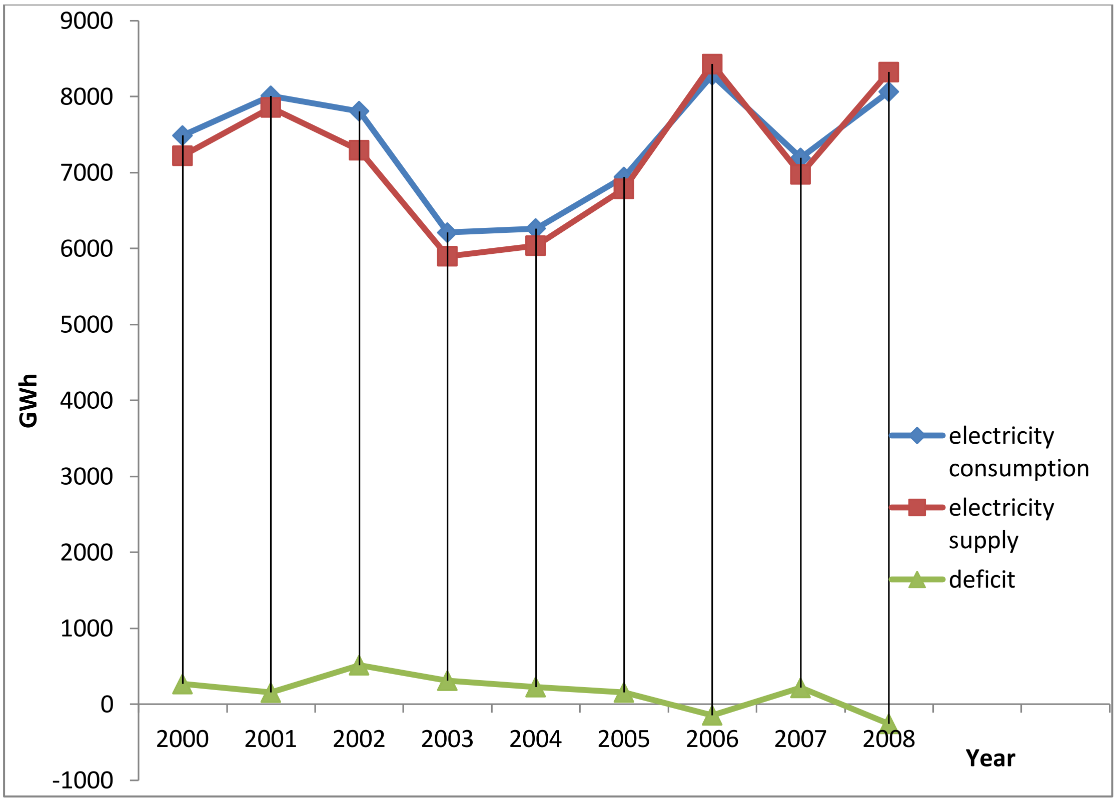

Figure 2.3: Evolution of Demand-Supply Gap in the Electricity Sector
Source: Author's compilation

Important to the analysis of the demand-supply gap is the existence of losses in the form of technical and non-technical losses of power within the electricity sector. Technical losses are largely caused by energy dissipated as heat in the restrictive conductors and equipment used for transmission, transformation and distribution of power. Non-technical losses on the other hand include pilferage, defective meters, and errors in accounting for electricity consumption. In practice, non-technical losses are largely confined to distribution while technical losses are present in generation, transmission and distribution. Generally, losses account for approximately 24% of electricity demand in Ghana which is largely driven by distribution losses (both technical and non-technical). In comparison, losses account for only 6.5% of demand in US and 21.21% in Rwanda. Transmission losses in Ghana are about 3.8% compared to an industry rule-of-thumb estimate of 3%.[11]

These huge losses in Ghana's electricity sector are partially responsible for the current trend of deficit within the electricity sector. One major step undertaken to curtail losses in the system has been the installation of pre-paid meters. It must be said here that, although, this is a good step, not much has been achieved in terms of national coverage. Currently, installation is on-going within the capital of Ghana. Table 2.2 below presents the evolution of losses in Ghana's electrical system.

Table 2.2: Share of losses of Electricity Demand (%)

Year	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Losses	19	18	21	26	26	24	21	22	24

Source: Energy Commission

From Table 2.2, total losses in the system increased continuously from 2001 to 2004. Though it decreased in 2005, its value was still high. From thereon, the total losses increased further reaching a maximum of 24% in 2008.

2.2.5 Ghana's historical Reserve Margins

The situation of deficit can further be demonstrated using reserve margin. Reserve margin is the amount by which generation capacity exceeds the projected peak demand, expressed as a percentage of peak demand. A high reserve margin means that the power system will be better able to withstand the unexpected loss of one or more generation plants or unexpected increases in load growth. A lower reserve margin would mean that the power system will not be able to withstand unexpected loss of one or more generation plants or unexpected increases in load growth. A simple way to determine the reserve margin is to compare the peak demand

[11] PSEC and GRIDCo: Ghana Power Reliability Report 2010
Ghana Energy Statistics: Ghana Energy Commission

to the unforced generation capacity. The unforced generation capacity is the generation capacity expected to be available during peak demand. The unforced generation capacity acts as a risk adjusted measure of available generation capacity. Thus, the unforced capacity adjusts the total capacity to account for the likelihood that some plants may be out of service during the peak period due to maintenance or unplanned outage. It provides an estimate of the net dependable generation capacity that is expected to be available during peak.

In 2009, Ghana had unforced generation capacity of 1,566 MW compared to peak demand of 1,423 MW. Thus, Ghana had only 140 MW of dependable surplus generation capacity to meet any load or generation contingency. This represents a reserve margin of 10.1%. By any measure this is a very low reserve margin. In fact, each of the individual units at Akosombo and Aboadze is more than 100 MW in capacity. This suggests that a loss of any one of these units would almost erase the reserve margin completely which will necessitate load shedding. This reserve margin compared to other countries is very low. In 2009 the reserve margins of US, South Africa, Malaysia and Mexico were 26%, 10.9%, 40.8% and 40.9% respectively. [12]

Most large wholesale power systems maintain a minimum reserve margin of 15% for reliable operations. However, reserve margins in practice are affected by the amount of surplus capacity needed to cover unexpected losses of a major input.[13] There are two core factors that affect the level of reserve margin at any point in time. These include the size of the system and the composition of units in the system. For example, for a small system with a peak demand of 1500 MW, a 15% reserve margin would be 225 MW, which may or may not be adequate to cover the loss of the single

[12] PSEC & GRIDCo Power Reliability Report for 2010
[13]PSEC and GRIDCo: Ghana Power Reliability Report 2010

largest system contingency. In contrast, a 15% reserve margin for a system with a peak demand of 15,000 MW is 2,250 MW, which will be adequate to cover the single largest system contingency. Thus, it is often the case for small systems to carry larger percent reserve margins that exceed the 15% threshold.

The composition of the generation units in the wholesale power system is also another factor that determines the choice of the reserve margin. For instance in a 2000 MW peak demand system served by ten 200 MW generators, a 200 MW spare (10%) would be sufficient to cover the loss of a single unit. However, if the same system is served by only two 1000 MW generators, the spare will have to be at least 1000 MW (50% reserve margin) to cover the loss of a single unit. The above analysis demonstrates that Ghana's wholesale power system requires a reserve margin of more than the 15% since Ghana's wholesale power system is a small system with only few generators in the system. Table 2.2, below presents the historical reserve margin[14] in Ghana.

Table 2.3: Ghana's historical reserve margins

Year	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Reserve margin	9.7	7.8	9.2	18.5	20.1	-0.3	-9.0	2.5	5.9	10.1

Source: Ghana Grid Company

From table 2.3, it is clear that the reserve margins of 2003 and 2004 exceeded the threshold level of 15%. These figures were artificially high since VALCO was forced out of operation to reduce system peak demand due to unreliable power supplies at Akosombo and Kpong. Thus, Ghana's bulk power system has failed to meet the threshold level of 15% in any single year in the last decade.

[14] Reserve margin=(Generation capacity-Demand)/demand

2.2.6 Export and Import of Electricity

Two major factors underlie export and import of electricity in Ghana: the need to meet growing peak demand and the variability of the Volta River flow rates. The major trading partners are Cote Devoir, Burkina Faso and Togo. For instance, Ghana has an exchange agreement with Cote D'lvoir for up to 200-250 MW of power import/export as the need arises on either side. In 2003, Ghana signed the ECOWAS Energy Protocol which eliminates cross-border barriers to trade in energy and facilitates investment in the energy sector. Alongside with the West Africa Power Pool (WAPP) these programmes provide a greater avenue for Ghana to trade power with the larger ECOWAS region.

Import represents external supply of electricity to augment local production while export represents external demand for electricity. Growing import of electricity for the country would mean that domestic production of power is not adequate in terms of meeting domestic requirements. Similarly a growing export would mean that domestic production is better able to cater for domestic demand for electricity. The balance between import and export of electricity is of significant importance to any economy. A positive net import[15] implies that domestic production of power is not self sufficient in terms of meeting domestic requirements of power. Contrary to the above, a negative net import means that local electricity production is able to meet domestic requirements. While a positive net import of electricity acts as a drain on the country's foreign reserve, a negative net import acts as a boost to the country's foreign reserve. Figure 2.4 below shows the trends in net import of electricity.

[15] Net imports is the difference between electricity imported and electricity exported

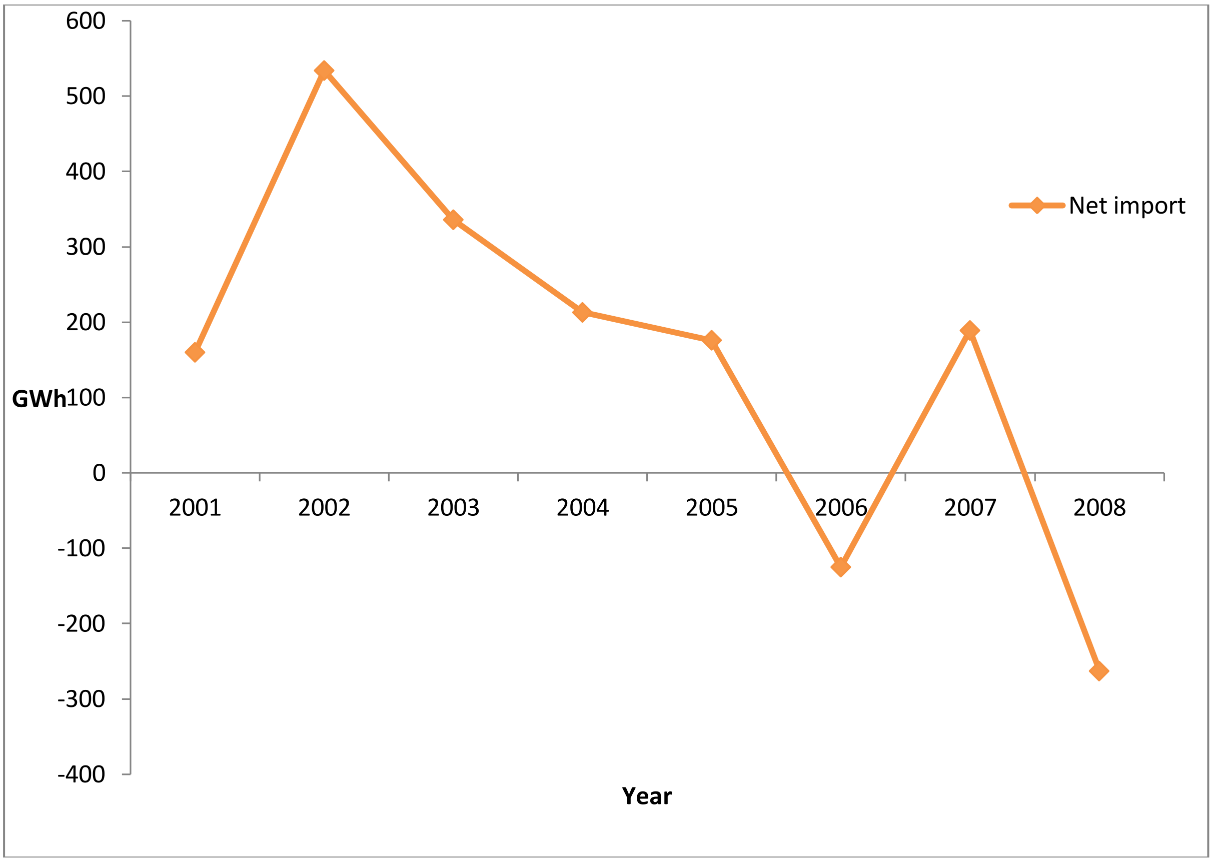

Figure 2.4: Trends in net imports of electricity in Ghana

Source: Author's computation with information from Energy Commission

From the information provided in figure 2.4 above, it was only in 2006 and 2008 that Ghana experienced a negative net import. Generally speaking, Ghana's electricity sector demonstrates a general trend of decreasing positive net import. Thus, domestically things are improving in terms of electricity generation in Ghana. I believe that with the completion of a number of projects such as Bui dam project, Suon-Asogoli Power Plant (SAPP), Osagyefo Power Plant, Kpong Power Project, Osono and CENPOWER projects, Tarkoradi T3 Project and Tarkoradi T2 Steam Component, there will be a turnover of events.

2.2.7 Economic Impact of Power Outages in Ghana

The cost of reliability failures is an integral component of the total cost to society of reliable power system. Power outages have both direct and indirect effects on utilities, companies and the economy as a whole. The direct effects include cost of repairing damaged equipment, lost generation revenue, reduction in equipment life, cost of damage to household electrical appliances, lost production and the spoilage of products. The indirect costs include opportunity cost of lost sales and revenue, increase in the cost of doing business due to uncertainty and the cost of on-site power requirement such as generators and uninterrupted power supplies. According to the World Bank estimates, the direct cost of power outages to African countries is about 2% of GDP. Using World Bank's estimate of Ghana's nominal GDP of $16.1 billion in 2008, this implies that power outages cost the economy more than US$ 320 million per annum.

The value of lost-load (VOLL) measures the cost of reliability failures in the electricity sector to customers. It is defined as the value placed by an average consumer on unsupplied unit of electric power. In other words, it provides a measure of the financial impact on consumers of power when there is curtailment of power. Since it measures consumers' willingness-to-pay to avoid power outages, it forms a critical component of evaluating the cost of power outages.

The value of the VOLL[16] depends on whether power is planned or unplanned and the consumer category. It is low for planned outages than unplanned outages since advance announcement gives users the opportunity to plan for the outage and re-optimise their activities accordingly. With regard to consumer class, VOLL is low for

[16] VOLL varies positively with electricity tariff. Thus, as electricity prices increases those customers who are willing to pay more will continue to use electricity while those who do not will reduce their consumption.

residential consumers but high for commercial and industrial consumers. This is so because it is relatively easy for residential consumers to adjust their behaviour. For instance, residential customers can adjust their behaviour towards power outages by using kerosene or torchlight as an alternative source of electricity which is not possible for commercial and industrial users. Table 2.3, below shows the estimated impact of power outages in terms of lost load and economic damages by consumer segment in 2009

Table 2.4: Economic impact of Power Outages (2009)

Sector	**VOLL (US$ million)**
Residential	217.2
Commercial	129.6
Industrial	598.4
Other	28.7
Total	$974

Source: PSEC & GRIDCo Power Reliability Report, 2010

From table 2.4, it is clear that the industrial sector is hugely affected by power outages followed by residential and commercial sectors. In total, power outages could cost Ghana’s consumers as much as US$ 974 million every year which represents 6% of GDP. This compared to the World Bank’s estimate is higher by 4%.

2.2.8 Official Demand Forecast and Actual Demand for Ghana

Accurate electricity demand forecast is an important pre-requisite for a well-functioning electrical system. Not only does it inform consumers to reconcile their demand portfolios with national demand but also help in making optimal investment decisions in the power sector. For an electrical system, like that of Ghana, where it is really difficult for utility companies to recover their cost of operation, developing accurate demand forecasts is of outmost importance. Official projections are made by VRA based on a compound annual growth trends. For instance, the 1997-2007 demand forecasts were based on the following assumptions:

- Domestic consumption of electricity is expected to increase at an annual constant rate of 5% until 1998, 4% until 2003 and 3% after 2004.
- VRA is expected to supply 2760 GWh/year to VALCO for the period 1997-2008

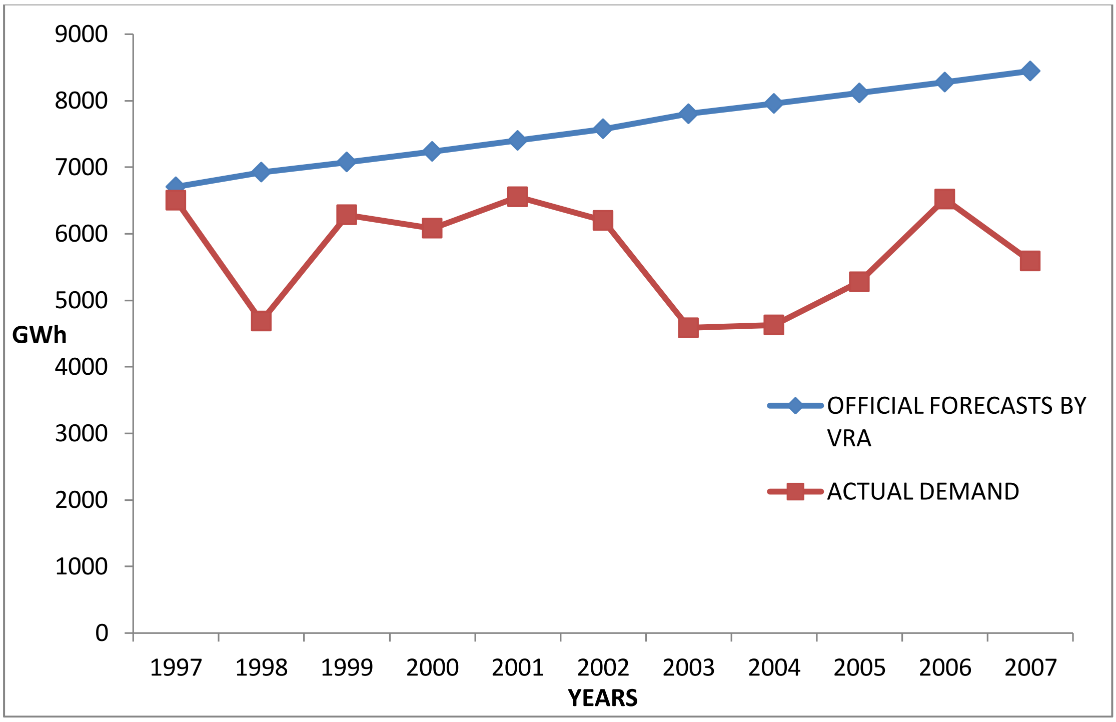

Figure 2.5: Comparison between official forecast and actual electricity demand[17]

Source: Author's compilation with information from VRA and Energy Commission

Over the years, the official forecasts of electricity demand have deviated widely from the actual. As shown in figure 2.5 above, the gap between official forecasts and the actual continues to widen. This raises questions of credibility and reliability of the current approach used for forecasting. Looking at the situation from the investment perspective, what this implies is that, there has been possible authorisation of capital

[17] Electricity demand is exclusive of exports and total system losses.

equipments/plants which have not been used over decades now. From the perspective of utility companies, what this implies is that there has been an increase in the cost of their activities largely due to misplaced investment. It is therefore, not surprising why service delivery by utility companies in the country has been sub-optimal. This poses the danger of an emergence of an unreliable power system in the country if there is not a change in gear.

2.3 Trend Analysis of the Time Series Variables

In this section we discuss the evolution of the time series variables from 1975 to 2008. The total domestic electricity consumption variable as shown in figure 2.6 below depicts an upward trend between the priods 1975 and 1982 and 1984 and 2008. However, we witnessed a sharp drop in domestic electricity consumption between 1983 and 1984 and in 2007. These periods were the periods in which Ghana experienced power crisis due to the fall in the water levels of Akosombo.

The time series plot of industrial efficiency, which is proxied by decreasing industrial electricity intensities, shows periods of stability (1975-1977 and 1986-1996), increasing (1980-1984, 1997-2003, 2006-2008) and decreasing (1977-1983 and 2004-2005) industrial electricity intensity. These periods respectively represent stable, decreasing and increasing industrial efficiency. Growth in the urban population as a percentage of total population generally declined between 1975-1976 and 1993-2008 and increased between 1979 and1992. However, we notice that the decline between 1993 and 2008 is very steady.

The share of industrial output in total ouput declined between 1976 and 1982 while it increased between the periods 1975-1976 and 1982 and 1985. However, we witnessed a stable growth in industrial output as percentage of GDP between the periods 1985 and 1994 and 1996 and 2008. The time series period plot of real GDP per capita depicts a valley-like feature with periods of declining (1975-1983) economic activities and increasing economic activities (1983-2008). From the above analysis the sharp drop in domestic electricity consumption experienced between 1983 and 1984 could be attributed to the fall in industrial output and real per capita GDP during this period. Also the upward trend movement in domestic electricity consumption between 1984 and 2008 is partially explained by the rise in real per capita GDP and industrial output.

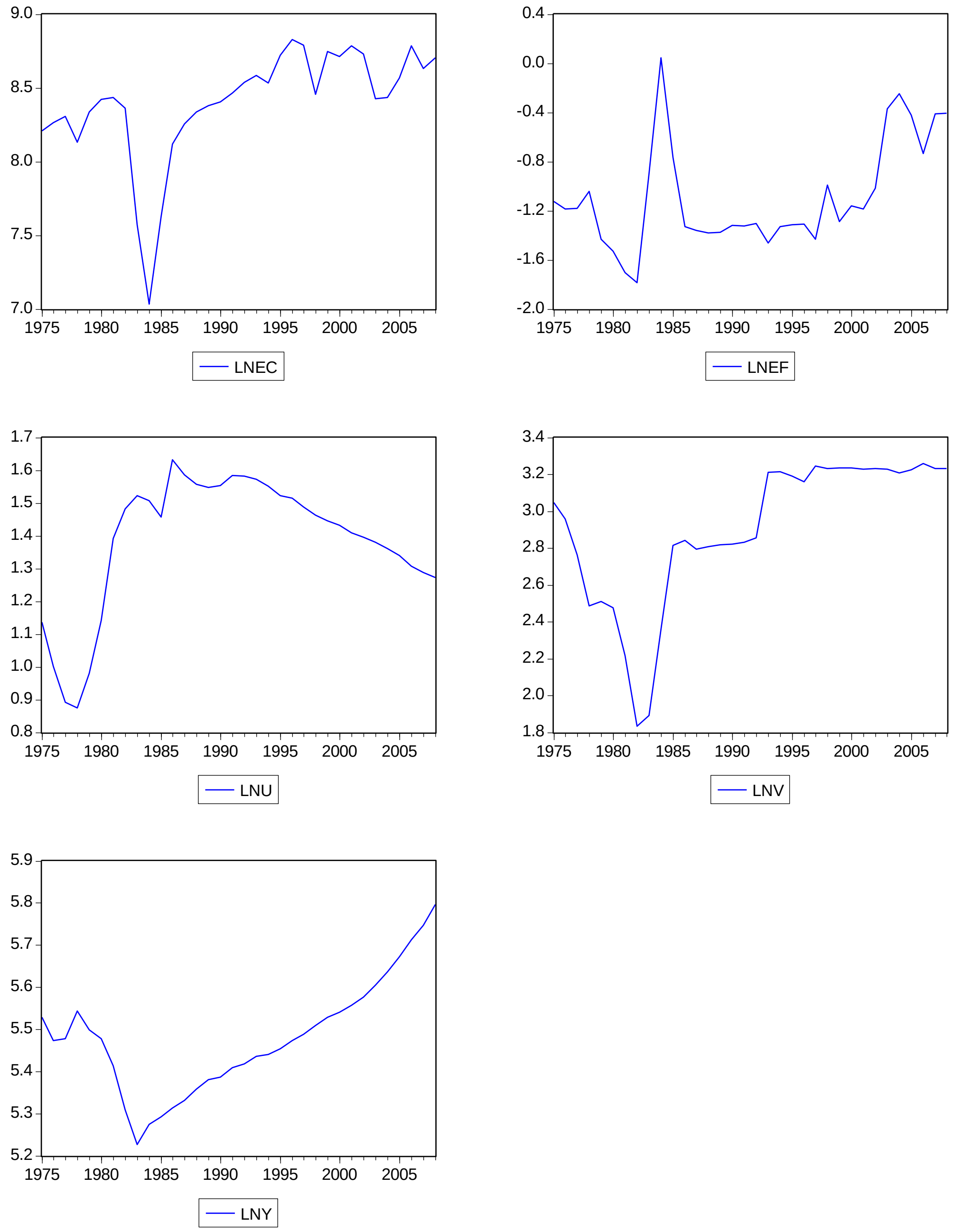

Figure 2.6: Trend Analysis of the Time series variables

2.4 Conclusion

In this chapter, it was revealed that demand-supply gap continues to increase in the electricity sector. Also it was revealed that there is declining reliance on external sources of electric power in Ghana. In terms of the economic impact of power outages, it was estimated that frequent power outages could cost the economy US$ 974 million every year which represents 6 percent of GDP. Analysis of the actual electricity demand vis-a-vis forecasted electricity demand also revealed that national load forecasts by VRA have largely overstated the actual electricity demand.

CHAPTER THREE

LITERATURE REVIEW

3.0 Introduction

This section includes literature that is pertinent to the issue under study. Generally, this section is categorized into two major subsections: theoretical review, empirical review.

3.1 Theoretical Review

According to the traditional demand theory, aggregate demand is explained by factors which shift the demand price-quantity schedule (Krichene, 2007). Following from consumer demand theory, demand for a good is said to be a function of its own price, price of related goods and income. The a priori restrictions on the parameters are based on the consumer theory of demand. According to this theory, the own price of a good is expected to have a declining influence on the demand for the good. In other words, the price elasticity is expected to be negative. The price of related goods is expected to have positive, negative or neutral effect on the demand for the good in question. Positive cross price elasticity implies that the goods in question are substitutes while a negative cross price elasticity implies that those goods are complements. Lastly, a zero cross price elasticity implies that those goods are unrelated to each other. The income variable, however, is expected to have a positive effect on the demand for the good. This presupposes that the good in question is a normal good, thus, a good with positive income elasticity.

Modelling energy demand follows from the traditional demand theory as suggested by Workings (1970), Houthakker (1951) and Houthakker and Taylor (1970). Electricity demand studies have been considered within the context of household/firm production theory. Within this framework, the household/firm combines electricity with capital to produce a composite energy demand commodity whose output is determined by the quantity of electricity bought and the stock of capital appliances (Narayan and Smyth, 2005). Where data is available, empirical modelling of electricity demand based on household/firm production theory expresses electricity demand as a function of own price, the price of related source of energy, real income, prices of electrical appliances and other factors that could affect consumer preferences such as cost of new technologies and weather conditions.

However, data limitations have led almost all existing studies to model electricity demand as a function of own price, price of substitutes, real income, population and temperature (Narayan et al, 2007). For example, Pindyck (1978) and Dahl (1994) modelled energy demand as a function of energy price, price of energy related good and income. Diabi (1998) modelled aggregate electricity consumption as a function of real income, average own price, price of appliances and temperature in Saudi Arabia. Amusa et al (2009) modelled electricity demand as a function of real income and average prices of electricity in South Africa. De Vita et al (2006) modelled electricity demand as a function of marginal electricity prices, real income, and mean minimum temperature. Thus, given that electricity demand is a derived demand, a lot of vital and sometimes countervailing factors change the pattern of electricity demand (Gellings, 1996). Therefore, factors affecting economic activities and consumption patterns can have an important influence on electricity demand.

The manner in which empirical data are measured may not conform to the structure implied by theory. For example, theory proposes that demand is a function of price and income; however, it may be difficult to find appropriate measures for these variables or even to generate them. According to the literature, the typical tariff schemes for electricity pricing are three: (i) constant rates, (ii) increasing block rates and (iii) decreasing block rates. In the first case, users pay the same price irrespective of the quantity consumed in KWh. The second approach makes the consumer pay more for each additional KWh of electricity consumed, while the third one implies an inverse relationship between price and quantity consumed. The last two tariff schemes have some methodological issues. This is about what kind of price to use in the electricity demand equation. Thus, whether to use average price, marginal price, infra-marginal or some combination of these prices. The difficulty associated with variable measurement and definition makes it difficult to translate theoretical relationships into empirical specification and estimation.

One of the first electricity demand studies was the one done by Houthakker (1951). According to Taylor (1976), this work estimated cross-section equations for each year of the sample, using a stock adjustment model which expressed the net changes in appliance stocks as the difference between the actual stocks of electricity consuming appliance and desired stocks of electricity consuming appliance. A major problem with this approach was how to treat the tariff structure, which composed of increasing block tariffs (IBTs), as well as the absence of an appliance demand equation. According to Gabor (1955), an IBT structure suggests a kinked budget constraint, and the assumption of a constant marginal or average prices leads to biased and inconsistent estimates. To go round the problem of an IBT structure, Houthakker estimated electricity demand using the marginal price corresponding to the consumers located in the highest price tier. In order to identify demand, those prices were introduced in the equation with a two year lag. Finally, it also considered the influence of appliance holdings by introducing some proxy variables to control for this fact.

In the United States, Fisher and Kaysen (1962) contested Houthakker's approach by proposing a "disease model". In their "disease model", they expressed net changes in appliance stock as the ratio of the actual stock of electricity consuming appliance at time t to the desired stock of electricity consuming appliance at time t-1. To go round the problem of an IBT structure, Fisher and Kaysen also estimated electricity demand using the marginal price corresponding to the consumers located in the highest price tier. Wilson (1970) and Anderson (1972) estimated electricity demand using regional-level data. Both employed appliance stocks as explanatory variables and use as a price proxy the average price for households consuming in the highest price tiers. The elasticities obtained in those studies show a very high dispersion, which could indicate problems of misspecification due to the treatment of price structures.

As the intricacy of the functional forms derived from the use of additional complicated schemes enlarged, discrete choice measures based on maximum likelihood estimation were ubiquitous. With regard to non-linear price structures, the most imperative work is that of Taylor (1976), who makes a complete review of all the electricity demand literature prior to 1973. Also, he pointed out some methodological issues associated with demand estimation when one considers non-linear price structures using micro data. According to Taylor, although the problem of how to treat non-linear price structure in demand estimation was considered by authors in the pre-1973 period much was not achieved in this light.

Halvorsen (1975) stressed the need of considering the tariff structure when estimating correctly identified demand equations. In order to solve this quandary, he estimated a separate equation for energy marginal price, which has quantity and other supply covariates as other explanatory variables. Both equations were estimated simultaneously, by two-stage least squares (2SLS). Halvorsen's model was later criticized by McFadden et al (1977), by modifying it. For these authors, the use of instruments in order to solve the simultaneity problem gives consistent estimates of the demand function parameters, but only if the appliance holding and usage decisions are considered as exogenous. If this is not true, they suggest that the probabilities of choosing alternative appliance portfolios should be included as instruments in the demand equation. In addition, the introduced specification allows for the calculation of price elasticities for each portfolio.

Similarly, the paper by Parti and Parti (1980) modelled households' consumption by developing a technique that allows estimation of consumption for each appliance. The total appliance stock is considered as an observed variable, but the consumption for each one is considered as a latent variable. By estimating a model that introduces a set of dummies for each appliance, the authors obtain price elasticities for the consumption of each appliance. Thus, the model allows analyzing appliances consumption changes derived from variations in households' characteristics, something that engineering-based models cannot do.

The work by Dubin and McFadden (1984) explicitly introduced discrete continuous framework in electricity demand estimation, jointly with the contributions stated by McFadden et al (1977). In this context, they derived the demand for electricity from a utility maximization framework. When considering the demand for electricity as a derived demand, the introduction of a two-stage methodology is straightforward. The first stage models the household choice among appliances, while the second stage uses the predicted choice probabilities as correction terms a-la-Heckman in the continuous demand equation. Dubin and McFadden tried to model the choice between energy-intensive appliances, such as space and water heating systems, but their extension to lower-intensity ones is also possible.

The Time of Day (TOD) pricing scheme was a subject in various studies, like the ones done by Hausman et al (1979) and Aigner and Hausman (1980). Those papers were among the first to have incorporated non-linear price modelling in electricity demand. The first study assumes that, for each time of the day, electricity is treated as a different good and tries to model the demand equations according to these facts. On the other hand, Aigner and Hausman (1980) estimated a demand equation that takes into account the sample selection bias present in this type of experiments. The corrected specification was then estimated by the methods explained in Hausman et al (1979).

Reiss and White (2001) work deserves special attention. These authors departed from the standard two-stage modelling of electricity demand, trying to incorporate all the available information of IBTs into a single likelihood function. In strict sense, they followed the tradition started by Hausman (1979, 1985) in labour markets and applied them to electricity demand. While keeping off appliance purchase decisions (i.e. taking appliance stocks as given), they estimated a demand function using General Methods Moments (GMM) techniques. For them, the choice of each price segment is similar to a Tobit model or a sample selection correction model, in which the censoring occurs not in the tails of the distribution, but in the middle of it. The obtained estimates do not suffer from the biases associated with the average/marginal price definition that plagued the pre-1973 studies (Taylor, 1976), as well as some problems such as the appropriate choice of instruments (Halvorsen, 1975; McFadden et al 1977).

Since Houthakker (1951) and the literature review by Taylor (1976), electricity demand models have focused on two main problems, related both with micro- economic choice theory and econometric issues.

- Price modelling, given that regulatory schemes often create non-linear prices (of which IBTs are the most prevalent).
- The influence of appliance stock holdings and purchase decisions on price and income elasticities.

To solve the first problem, three different approaches have been tried as described above. The first one suggests the inclusion of average or marginal prices as exogenous variables (Houthakker, 1951; Fisher and Kaysen, 1967; Halvorsen, 1975). In the second half of the 1970s, the solution provided by McFadden et al (1977) was to incorporate marginal prices and instrumentalizing them by all the prices in the tariff structure, so that consistent estimates of relevant elasticities could be obtained. Finally, Reiss and White (2001) suggest that all relevant prices should be included into an expression for a given household expected consumption.

Regarding the second problem, the choice of certain appliance stocks became consistent with development of micro economic theory. The econometric modelling of choice behaviour was developed after the introduction of flexible functional forms and duality theory. Discrete choice models, sample selection corrections and discrete-continuous combinations (McFadden, 1973, 1974; Heckman, 1974, 1979; Hausmann, 1984) allow introducing this component in electricity demand estimation, providing estimates of electricity consumption for appliance portfolios, or even for each appliance.

3.2 Empirical Review

This section surveys actual studies that have been previously carried on the topic and evaluates what these studies have and have not accomplished. Extensive review include Kouris (1983), Prosser (1985), Kim and Labys (1988), Siddayoo (1993) and Holtedahl and Joutz (2004) just to mention a few. This section is organized around the following sub-sections; empirical studies on total energy demand, electricity demand, and economic growth-energy consumption nexus.

3.2.1 Empirical Studies on Energy Demand

Mostly in the literature, empirical studies on energy demand estimates have focused on what is referred to in the literature as "energy approach". In works that have adopted this approach to energy demand estimates, each energy component is reduced to a common "energy currency". These works include the works of such authors as Kouris (1983), Prosser (1985), Kim and Labys (1988), Siddayoo (1993), Pessaran et al (1998), Pit (1985) and Borges and Pereir (1992) just to mention a few.

In a dynamic modelling framework, Kouris (1983) used aggregate time series data from 1961 to 1981 for OECD countries to study primary energy demand. In his study a short-run price and income elasticity of -0.15 and 1.08 was found respectively while a long-run price elasticity of -0.43 was also found. The estimated elasticities obtained in this study imply that the degree of price sensitivity of energy demand within the short-run is lesser than that in the long-run. This conclusion follows from economic theory which says that in the short-run because individuals' degree of adjustability is low, demand response to price changes tends to be low. However, in the long-run when individuals have adjusted their consumption portfolios; their response of demand to price changes tends to be more elastic. In a related study conducted by Prosser (1985) for OECD countries from 1960 to 1982, Prosser estimated the short-run price and income elasticity to be -0.22 and 1.02 and a long-run price elasticity of -0.40.

Using cross sectional data, Kim and Labys (1988) estimated the price elasticity for the manufacturing sector to be -0.47 and for the industrial sector to be -1.01. The estimated elasticities in their work imply that the degree of responsiveness of industrial sectors consumption of energy to price is more than that of the manufacturing sector. Given that the manufacturing sector is part of a whole (industrial sector), it is not surprising. In a more disaggregated study which focused on the manufacturing sector, Siddayoo et al (1993) examined energy demand for the textile and food processing industries. In their study they estimated the price elasticity for the textile industry to range between -0.25 to -0.71 and that of the food processing industry to be between -0.26 and -0.52. Taking the means of these estimates the conclusion of their paper implies that the textile industry is more price sensitive than the food processing industry. This goes to suggest that even within specific sectors there are variations in price elasticity.

Also Pessaran et al (1998) carried out a study on energy demand for the transport and residential sectors. In their study, they estimated a price elasticity of between -0.005 and -0.569 and an income elasticity of between 0.376 and 2.947 for the residential sector. However, for the transport sector a price elasticity of between 0.000 and -1.753 was estimated. Thus, taking their averages it is evident that the transport sector is more price sensitive than the residential sector.

From the aforementioned literature, the decreasing effect of energy price and increasing effect of income on energy demand is confirmed. Also it is clear from the above that not only are there inter-sectoral price elasticity variation but also intrasectoral price sensitivity variation. Although the "energy approach" is useful as a crude measure for checking compatibility of various energy types, it has been criticized as been inappropriate tool for analyzing demand for specific energy type. This is as a result of the varying technological efficiencies and the wide ranges of substitutability between the different energy types in their various applications.

3.2.2 Empirical Studies on Electricity Demand

Following from the disadvantages associated with the" energy approach" a more disaggregated approach which treats demand for specific energy type was deemed appropriate. Since this realization, several studies have concentrated on a more specific energy type study ranging from electricity to natural gas, oil and biomass. Electricity is one of the energy types that have attracted a lot of interest due to its versatility. Several studies have been conducted in both developed and developing countries on electricity demand using either micro or macro level data. Studies cover issues such as residential or household demand for electricity, industrial demand for electricity, commercial demand for electricity, and total electricity demand.

The interest in the study of electricity demand largely started in the United States and United Kingdom. The study by Houthakker (1951) forms part of the earlier works conducted for the United Kingdom. In his study, Houthakker focused on residential electricity consumption using the stock adjustment model. The study found the income elasticity to be 1.17, a price elasticity of -0.89 and a cross elasticity with respect to the marginal price of gas of 0.21. However, Houthakker was silent on whether the estimated elasticities referred to the short-run or the long-run.

Rejecting the stock adjustment model by Houthakker, Fisher and Kaysen (1962) proposed a "disease model" to analyze both long-run residential and industrial demand for electricity in United States. They based their rejection of the stock-adjustment model on the observation that

...our analysis is concerned with the stock of certain physical units; units, moreover, which have the property that a given household generally owns one of them at most. Net changes in the stock, therefore, come about overwhelmingly by the purchase of new units by households not previously owning one. While it is true...that the demonstration effects of other household's possessions may influence such purchases, it is unreasonable to use a model which makes such purchases proportional to the difference between desired and actual stock. The actual stock that counts here is zero and the fact that the other households in the economic aggregate being considered owns the good already is not relevant in this place". (Fisher and Kaysen, 1962)

In the "disease model" instead of defining net changes in the appliance stock as the difference between the actual and desired capital stock as defined by Houthakker, Fisher and Kaysen defined the net changes in the appliance stock as the ratio of the i^{th} appliance stock at time to the i^{th} appliance stock at time t-1. In general, the study found the net changes in the appliance stock to depend mainly on changes in long-run income or population and in the number of wired houses. However, the price electricity was found to have no effect on electricity demand. The estimated elasticities in this study confirmed the intuition that substitution possibilities make demand more elastic in the long-run.

In a related study, Houthakker and Taylor (1970) estimated an equation for personal consumption expenditure for electricity based on the state-adjustment model of consumption for UK. In their study they found the short-run and long-run price elasticity to be -0.13 which contradicts what has been largely established in the literature: that is short-run price elasticity is lesser than the long-run price elasticity. However, the short-run and long-run estimate of income elasticity of 0.13 and 1.93 respectively confirms what has been established in the literature. Using the flow-adjustment model by Houthakker and Taylor, Houthakker et al (1973) also analysed residential demand for electricity from 1960 to 1971. In their study they estimated the short-run and long-run price elasticity to be -0.09 and -1.02 respectively which contrast earlier estimates by Houthakker. The short-run and long-run income elasticity was 0.14 and 1.64 respectively.

Wilson (1970) reached a conclusion which was in sharp conflict with that reached by Fisher and Kaysen in a study on the residential demand for electricity for the US. In his study, Wilson found the price of electricity, average price of natural gas and family income to be statistically significant. Of particular interest was the result of the substantial negative price and income elasticity. Wilson interpreted his model as representing the long-run demand function and accordingly concluded that his results vis-a-vis the price elasticity of demand are in sharp conflict with that of Fisher and Kaysen, who found little or no influence of price on the long-run demand for electricity.

In a similar study, Anderson (1971) rejected the conclusion reached by Fisher and Kaysen in a study that analysed producers' demand for energy by the US primary metals industry from the period 1958 to 1963. Anderson adopted Fisher and Kaysen approach but with some extensions. Unlike Fisher and Kaysen that focused on producers demand for electric power, Anderson focused on total producers' demand for energy. Also in Anderson's study allowances were made for quantity discounts in the purchase of energy inputs, effects of supply equations on demand equations, competing input prices and the effect of variations in the composition of the industry. Anderson estimated the price elasticity of electricity demand to be -1.94. Thus, in keeping with the result of Fisher and Kaysen, the price elasticity is seen to be negative, substantial and highly statistically significant. Baxter and Rees (1968) confirmed Fisher and Kaysen's result using quarterly data from 1954 to 1964 in a study on industrial demand for electricity. In their study, they concluded that relative price changes are not unambiguously an important determinant of growth in industrial electricity consumption. The chief determinants, however, are growth in output and changes in technology.

Thomas and Mackerron (1982) examined the determinants of industrial electricity demand in the UK from 1959-1980. In their study they also found that factors such as adjustment in industrial structure, technical change and the decline in self-generation of electricity as been important contributors to more than 40 percent of demand growth in the period. In their study they recommended that a more detailed sector based analysis taking into account the structural and technical changes and the developments in self-generation should be considered.

Mount et al (1973) analysed electricity demand for three consumer classes: residential, commercial and industrial, using a pooled cross-section data from 1947 to 1970. Their estimated long-run elasticities showed that electricity demand in general is price elastic for all the consumer classes and becomes increasingly elastic as price rises. However, demand is generally inelastic with respect to income and for residential and industrial classes the elasticity approaches zero as income increases. The income elasticity for commercial demand is, however, slightly inelastic over a wide range of income levels. Population exhibits approximately unit elasticity for all classes with the elasticity for the prices of gas and appliances being inelastic. Lyman

(1973) confirmed the result obtained by Mount et al (1973) in a similar study that analysed electricity demand for three consumer classes: residential, commercial and industrial, using data from 1959 to 1968. Lyman assumed demand for electricity to be a function of price of electricity, price of gas, index of other prices, vector of economic and demographic variables and a vector of climate variables. In his result, Lyman also found the price elasticity of demand to be elastic for all the consumer class. The study also found that residential demand is positively correlated with income.

However, in a similar study by Zauresh Atakhanova and Peter Howie (2007), they found the price elasticity of demand in all sectors to be low and income elasticity of demand in the aggregate and all sectoral models to be greater than unity. Specifically the residential income elasticity was the lowest. Also at the aggregate level they found that a 1% improvement in industrial efficiency would lead to a 0.33% reduction in electricity demand. The study found structural changes in the economy to have a significant positive relationship with electricity demand. Specifically the study found that a 1% increase in industry's share of GDP would increase electricity demand by 0.28%.

Although earlier studies focused on US and UK, later studies focused on Asia, Europe, South America, and Africa. Holtedahl and Joutz (2004) examined the residential demand for electricity in Taiwan as being dependent on household disposable income, population growth, the price of electricity and the degree of urbanization. Using an error correction model to separate the short and long term effects, the study found the income elasticity of electricity demand to be unitary elastic in the long-run and the own-price elasticity to be inelastic. The study also found the short-run income and price effects to be smaller than the long-run income and price effects. In all the study concluded that social, economic and demographic factors play a key role in the demand for electricity. Psiloglou et al (2009) confirmed the results of Holtedahl and Joutz in a comparative analysis of the determinants of electricity demand in households and commercial sectors for London and Athens and reached the same conclusion that social, economic and demographic factors play a key role in the demand for electricity.

Halvorsen and Larsen (2001) examined the factors responsible for increased household electricity demand in Norway by using annual consumer expenditure data. They found that increases in household size, average consumption of electricity per household, stock of appliances, income and the number of rooms to be the main factors responsible for increasing household demand for electricity. This was confirmed in a related study: the role of economic and non-economic factors in the determination of households demand for electricity in district Peshawar by Naeem et al (2010). The study used primary data for 200 households of city rural division during November-December 2009 using a multinomial logistic model. The study also concluded that income; number of rooms, price of electricity, weather and education are the important determinants of households demand for electricity in district Peshawar.

Ang et al (1992) examined the residential demand for electricity for Singapore from 1975 to 1990. In their study they found the short-run price elasticity of electricity demand to be -0.10 and the short-run income elasticity of electricity demand to be 0.30. The long-run price and income elasticity of electricity demand were estimated to be -0.35 and 1.0 respectively. Thus, they found income to have a positive effect on household consumption of electricity and price to have a negative effect on household demand for energy services. This conclusion was confirmed by

Al-Salman (2007) in a study: “factors that affect household demand for energy in Kuwait”. In his results it was also concluded that increases in price has reduced impact on energy demand. Athukorala and Wilson (2009) used unit root, error correction and cointegration to find the short and long-run determinants of household’s demand for electricity in Sri Lanka during the period 1960-2007. The results showed that demand for electricity in the long run increases due to increase in household’s income. The study concluded that increases in household income in the future should also be included in policies regarding the production of electricity because focusing only on current per capita consumption and population growth may give wrong estimates of households demand for electricity.

However, in a study by Ziramba (2008): “determinants of household demand for electricity in South Africa” he concluded that there was no effect of changes in electricity prices on household demand for electricity which confirms Fisher and Kaysen results. However, they found households’ income to have a significant positive effect on household demand for electricity. In a related study Louw et al (2008) examined two typical low-income rural sites in South Africa, Antioch and Garagapola, where the Electricity Basic Services Support Tariff (EBSST) was piloted in 2002. The paper assessed which factors affect the decision-making process for electricity consumption within these households. A log-linear regression model was used. It was found that income, iron ownership, and credit obtained positively affect the consumption levels within these households, while wood fuel usage has a negative significant effect. However, Price and cross-price elasticities were difficult to assess due to lack of data within the sample.

Sterner (1989) studied electricity consumption in the manufacturing sector in Mexico from 1966 to 1981 and finds price elasticity of -0.5. In a similar study, Ramcharran (1990) conducted a study on industrial and commercial demand for electricity for Jamaica. In his study he found the income elasticity for both small industry and commercial and large industry and commercial to be 0.34. Thus, small and large industries' and commercials' electricity demand response to income changes are the same. However, in terms of the price effects he found the price elasticity for small industry and commercial to be -0.26 whiles that for large industry and commercial was estimated to be -0.19. That is the price sensitivity of small industry and commercial to electricity consumption is higher than that of large industry and commercial.

Huang (1993) examined the electricity-economic growth nexus for China for the period 1950-1980. In this study a test of causality was not conducted but rather carried a correlation analysis among variables and found the income elasticity of electricity consumption to be greater than unity. However, using macroeconomic data and cointegration technique to analyze the main determinants of electricity demand in the People's Republic of China, Lin (2003) estimated the income elasticity to be 0.86 for the pre-reform period (1952-2001) and that for the after 1978 economic reforms to be 0.78. The study also revealed that, electricity demand in China is positively related to population growth and negatively related to structural changes in the industrial sector, electricity prices and efficiency improvement in the industrial sector. Further, both efficiency and structural change variables were found to contribute more to electricity demand in the post reform years. Using a cointegration analysis the study revealed a more significant stable relationship among the variables after China's economic reforms (1978), when all factors were more responsive to market forces.

Al-Azzam (2002) wrote a dissertation on demand for energy in Jordan. In his study he captured demand for energy, demand for electricity, and demand for refined petroleum products and forecasted demand for energy using error correction model, Autoregressive Distributed Lag model, Johanson test and Stock Watson dynamic OLS methodology. In his study he found that while prices have a neutral impact on energy consumption, economic growth is likely to be accompanied by proportional increases in electricity demand. Issa and Bataineh (2010) investigated into the main determinants of demand for electricity in Jordan during the period 1979-2008 using least squares estimation. In their study it was found that per capita real GDP had a significant positive effect on the demand for electricity. However, real prices of electricity and efficiency variables were found to have a significant negative effect on the consumption of electricity. This result contradicts that obtained by Al-Azzam (2002).

Chang and Chambo (2003) estimated a double-log functional form of the demand equation using monthly Mexican electricity data for residential, commercials and industrial sectors. Income, prices and a non-parametric temperature measure were used as explanatory variables and the income elasticity was allowed to evolve slowly over time by employing the time varying coefficient (TVC) cointegrating model. The specification of the proposed TVC cointegrating model was justified by testing it against the spurious regression and the usual fixed coefficient (FC) cointegrating regression. The study revealed that the income elasticity has followed a predominantly increasing path for all sectors during the entire sample period and that electricity prices do not significantly affect the residential and commercial demand for electricity in the long run in Mexico. Amusa et al (2009) analysed the determinants of aggregate demand for electricity in South Africa by using Bounds testing approach in an autoregressive distributed lag framework during the period 1960-2007. The results showed that demand for electricity was greatly affected by changes in income; however, changes in price of electricity had no effect on the demand for electricity.

Ang (1988) examined the determinants of per capita electricity consumption for four Asian countries from 1960 to 1984 and found the income elasticity to be between 1.39 and 2.63 and the price elasticity to be between -0.11 and -0.64. Rahman (1982) in a similar study found the price elasticity to be -0.59 and income elasticity of 1.71.

Hondroyiannis (2004) examined the factors which brought changes in aggregate demand for electricity in Greece both in the short-run and long-run periods. The study concluded that in the long-run real income, price level and weather played an important role in household demand for electricity. However, in short run changes in demand for electricity were affected only by weather condition. Also Carcedo and Otero (2005) examined the impact of weather on electricity demand for Spain using smooth transition, threshold regression and switching regressions models. The study concluded that weather played strong role in changing electricity demand in Spain.

Kamerschen and Porter (2004) using a period from 1973-1998 estimated residential, industrial, and total electricity demand by a partial adjustment approach and a simultaneous approach. The simultaneous equation model yielded negative price elasticity estimates for the residential, industrial and total electricity while the flow-adjustment models yielded positive price elasticity estimates in some cases. This suggests that the flow-adjustment models fail to identify proper supply considerations that may be influencing prices. The simultaneous equation approach suggests that residential customers are more responsive to price changes than industrial customers. In their study also weather seems to have the greatest impact on the residential sector and cold weather appears to affect demand more than hot weather.

Erdogdu (2006) using cointegration analysis and autoregressive integrated moving average modelling examined electricity demand for Turkey applying quarterly time series data for the period 1984-2004. The study concludes first that consumers respond to price and income changes is quite limited and second that the current official electricity demand projections highly overestimates the actual electricity demand which may endanger the development of both a coherent energy policy in general and a healthy electricity market in particular. Erdogdu (2007) also concluded that income and price influence electricity demand in Turkey.

3.2.3 Energy Consumption-Economic Growth nexus

The study of the empirical investigations of the causal relationships between energy consumption and economic growth can be analysed through two lines; the hypothesis criteria (Apergis and Payne, 2009) and the generation criteria (Guttormsen, 2004). The hypothesis approach analyses the causation in light of whether studies concluded that energy consumption causes economic growth or otherwise or both. Along these lines, studies on the empirical investigations of the energy-economic growth nexus have been grouped under four main hypotheses; the Growth-led-Energy hypothesis, the Energy-led-Growth hypothesis, the Energy-led-Growth-led-Energy hypothesis, and the neutrality hypothesis.

The Growth-led-Energy hypothesis asserts that economic growth leads to energy consumption. This implies that energy conservation is a viable option. The Energy-led-Growth hypothesis on the other hand asserts that energy consumption leads to economic growth. This suggests that energy conservation is not a viable option. The Energy-led-Growth-led-Energy hypothesis asserts that there exists a bidirectional causality between energy consumption and economic growth. Lastly, the neutrality hypothesis asserts that there is no causal relationship between energy consumption and economic growth.

Along the lines proposed by Guttormsen (2004), studies on the empirical investigations of the energy-economic growth nexus have been classified along three lines; the first generation studies, the second generation studies, and the third generation studies. The first generation studies consists of studies that basically used the traditional Vector Autoregressive Models (Sims, 1972) and the standard Granger causality test. The main weakness associated with this generation of studies is that they assume the series to be stationary. As a result the second generation of studies proposed cointegration (johansen, 1991) as the appropriate tool to use in analysing the causal relationship between energy consumption and economic growth. Thus, in the second generation of studies, pairs of variables were tested for cointegration relationship and an error correction model was estimated to test for causality (Engle and Granger, 1987). However, given the possibility of more than one cointegrating vectors, the second generation studies approach was deemed inappriopriate. This led to the third generation of studies, which proposed a multivariate approach that allowed for more than two variables in the cointegrating relationship. This approach facilitates estimations of systems where restriction on cointegrating relationship can be tested and information on short-run adjustment can be investigated.

There are two main problems with the third generation studies. First the third generation studies impose restrictions that the variables should be integrated of order one. Secondly, the variables will have to be cointegrated before a test of causality can be possible. This has led to the emergence of a new generation of study; fourth generation studies. These studies use the Toda and Yomamoto Granger Causality test, which is based on the Autoregressive distributed lag model. In this generation of studies, restrictions are not imposed on the variables. Thus, causality is still possible even when variables are integrated of order zero, one or both. In other words, this approach allows for the test of causaity even when variables are not cointegrated.

Following from the above classifications of empirical studies on the energy-economic growth nexus, this study adopts the hypothesis criteria. Hence, the empirical studies are grouped under four testable hypotheses.

3.2.3.1 Growth-Led-Energy Hypothesis

The empirical study on the causal relationship between energy consumption and economic growth started with the seminal work of Kraft and Kraft (1978). Their work forms part of the first generational studies. Using an approach based on the standard Granger causality test and annual data on energy consumption and economic growth for the period 1947-1974 for USA, they found evidence of unidirectional causality running from economic growth to energy consumption. Akarca and Long (1980) argued that the inclusion of the oil crisis years (1973-1974) was the reason behind the conclusion reached by Kraft and Kraft (1978). Akarca and Long (1980) contested this results by saying that, using “a more homogenous”, 1950-1968 period, the unidirectional causality from economic growth to energy consumption diminishes.

Using the same approach and quarterly data (1973-1981), Yu and Hwang established evidence of unidirectional causality running from GNP to energy consumption for South Korea. Yu and Choi (1985) using the sample period 1954 to 1976 carried out a verification study on the causal relationship between energy consumption and economic growth in a multi country studies. In the case of South Korea they found unidirectional causality running from GNP to energy consumption. Soytas and Sari (2003) using the sample 1950 to 1992 carried out a multi country study on the causal relationship between energy consumption and economic growth. In their study they also found causality running from GDP to energy consumption for South Korea, Italy and Japan. Also Wankeun and Kihoon (2004) using sample period 1981 to 2000 confirmed the conclusion of unidirectional causality running from income to energy consumption for South Korea.

Lin (2003) whose work forms part of the third generation studies, conducted a study on the causal relationship between electricity consumption and economic growth for China covering the period 1978-2001 and concluded that a unidirectional causality runs from economic growth to electricity consumption. Also Ghosh (2002) examined the causal relationship between electricity consumption and economic growth for India for the period 1950-1997. He found evidence of unidirectional causality running from economic growth to electricity consumption. Masih and Masih (1996) in multi-country study found evidence of unidirectional causality from income to energy consumption for Indonesia. Kees (2007) using data from 1970 to 2003 also found evidence of unidirectional causality from income to energy consumption for Turkey.

In a study by Squalli and Wilson (2006) in the cooperation council for Arab states of the Gulf (GCC), this comprised: Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates, evidence in support of the efficacy of energy conservation measures was found for five of the six countries except Qatar. Also Mahmoud (2006) and Al-Iriani (2006) both confirmed the evidence of unidirectional causality from income to economic growth for GCC countries.

Chien-chiang et al (2007) applies a new panel data stationarity testing procedure with panel VARs that employ the Generalizes Method of Moments (GMM) techniques to investigate the dynamic interactions between energy consumption per capita and real GDP per capita for twenty-two (22) developed and eighteen (18) developing countries from 1962-2002 and 1971-2002 respectively. The study found a unidirectional causality from real GDP to energy consumption in developing countries. Nachane et al (1988) using Engle and Granger cointegration approach found evidence of long-run relationship between energy consumption and economic growth for eleven developing countries and five developed countries but found evidence of unidirectional causality from real GDP to energy consumption in developing countries.

Wolde-Rufael (2006), which forms part of the fourth generation studies, used Toda and Yamamoto's granger causality test to examine the causal relationship between energy consumption and economic growth for seventeen Africa countries for the period 1971-2001. He found evidence of causality running from GDP to energy consumption for Algeria, Congo Democratic Republic, Egypt, Ghana and Ivory Coast. The case of Congo is confirmed by Akinlo (2008). Twerefo et al (2008) whose study form part of the third generation studies applied Johansen approach of cointegration within a multivariate framework to analyze the causal relationship between energy consumption and economic growth for Ghana for the period 1975-2006. Their results indicated that in Ghana there exists a unidirectional causality running from economic growth to energy consumption which confirms Wolde-Rufael's conclusion but contradicts with that reached by Lee (2005) and Akinlo (2008). In a more disaggregated framework, Twerefoe et al found a one way causational relationship which runs from economic growth to petroleum and to electricity consumption. Also the conclusion reached for Ivory Coast by Wolde-Rufael contradicts that reached by Akinlo (2008). Akinlo (2008) found evidence of unidirectional causality running from economic growth to energy consumption for Sudan, Zimbabwe and Congo.

The general comclusion from these studies is that energy conservation policies such as phasing out of energy subsidies are viable.

3.2.3.2 Energy-Led-Growth Hypothesis

Yu and Choi (1985) in a multi-country study on the causal relationship between energy consumption and economic growth found evidence of unidirectional causality running from energy consumption to GNP in the case of Philippines. This was confirmed in a study by Lee (2005). However, in the case of South Korea, lee (2005) found evidence of unidirectional causality from energy consumption to economic growth using the sample 1971 to 2006 which contradicts Yu and Choi (1985). Also in China, Lam and Shiu (2004) using a sample period of 1971-2000 found evidence of unidirectional causality running from electricity consumption to economic growth. This conclusion contradicts that reached by Lin (2003).

Soytas and Sari (2003) found that energy consumption causes GDP in Turkey, France, and Germany. The case of Turkey was confirmed in a study on the causal relationship between electricity consumption and economic growth by Altinay and Karagol (2005). In that study, an evidence of unidirectional causality running from electricity consumption to income was found. Also Asafu-Adjaye (2000) confirmed evidence of unidirectional causality from energy consumption to economic growth for Turkey. These results contradict that reached by Kees (2007).

Fatai et al (2004) using a sample period of 1960 to 1999 found evidence of unidirectional causality from energy consumption to economic growth for Indonesia, India, and Thailand. The case of India and Indonesia is confirmed by Masih and

Masih (1996), Lee (2005) and Asafu-Adjaye (2000) while Masih and Masih (1996) and Lee (2005) confirmed that of Thailand. Lee (2005) also found evidence of causality running from energy consumption to economic growth for Philippines, Sri Lanka, Malaysia, Pakistan and Argentina. Imran et al (2010) confirmed the conclusion reached for Pakistan.

Chen et al (2007) using a dynamic panel error correction model on a panel of ten(10) Asian developing countries found that causality runs from electricity consumption to economic growth in the short-run. Mehra (2007) applies panel estimation techniques to eleven (11) oil exporting countries and found evidence of a strong unidirectional causality running from energy consumption to per capita GDP.

In a recent effort, Ciarreta and Zarraga (2008) apply a heterogeneous panel cointegration tests and panel system general methods of moments (GMM) to estimate the causal relationship between economic growth and electricity consumption for twelve (12) European countries. They found no evidence of causation in the short-run but found a long-run relationship running from electricity consumption to GDP. Paresh et al (2006), which forms part of the fourth generation of studies, examined the nexus between electricity consumption and economic growth for Fiji for the period 1971-2002 using Bounds approach to cointegration and found that in the long-run causality runs from electricity consumption and labour force to GDP.

Apergis and Payne (2009, 2010) examined the causal relationship between energy consumption and economic growth for a panel of eleven (11) countries of the commonwealth of independent states. They found unidirectional causation from energy consumption to economic growth in the short-run. Wolde-Rufael (2006) found causality from energy consumption to GDP for Cameroon, Morocco and Nigeria. Gbadeho and Chinedu (2009) confirmed the Nigeria case (using annual data from

1971 to 2005) that energy consumption is a strong determinant of economic growth. However, the case of Cameroon contradicts the conclusion reached by Akinlo (2008). Lee (2005) applied panel estimation techniques to eighteen (18) developing countries including India, Kenya and Ghana, and found evidence of causality running from energy consumption to GDP. This conclusion contradicts that reached by Wolde-Rafael (2006) and Twerefo et al (2008) for Ghana. Chali et al (2010), using panel data techniques, investigated the long-run relationship between energy consumption and GDP for a panel of nineteen (19) African countries (COMESA) for the period 1980-2005 and found that causation runs from energy consumption to GDP for low income COMESA countries.

The general conclusion from these papers is that these economies are energy dependent hence energy conservation is not a viable option.

3.2.3.3 Energy-Led-Growth-Led-Energy Hypothesis

Lee (1997) conducted a study on the causal relationship between energy consumption and economic growth for South Korea and Singapore for the period 1961 -1990 and found evidence of bidirectional causality between energy consumption and GDP for both countries. Glasure and Lee (1997) using the sample 1961 to 1990 also found results of bidirectional causality between energy consumption and economic growth for South Korea and Singapore. The case of South Korea was confirmed in a study by Oh and Lee (2004) using the data period 1970 to 1999 for South Korea.

Masih and Masih (1996) using cointegration approach established a long-run relationship between energy consumption and income for India, Pakistan and Indonesia but no long-run relationship for Malaysia, Singapore and the Philippines.

Paul and Bhattacharya (2004) found evidence of bidirectional causality between energy consumption and economic growth for India. In other works by the authors, a long-run relationship was established for South Korea and Taiwan, and Thailand and Sri Lanka in 1997 and 1998 respectively. Soytas and Sari (2003) found that evidence of bidirectional causality between energy consumption and economic growth existed in Argentina. Also Yang (2000) using the period 1954 to 1997 found evidence of bidirectional causality between energy consumption and economic growth for Taiwan.

Chien-chiang et al (2007) using panel estimation techniques to investigate the dynamic interactions between energy consumption per capita and real GDP per capita for twenty-two (22) developed and eighteen (18) developing countries from 1962-2002 and 1971-2002 respectively found evidence of bidirectional causality between energy consumption and real GDP for developed countries. Also Chen et al (2007) using a dynamic panel error correction model on a panel of ten(10) Asian developing countries found a bidirectional relationship between electricity consumption and economic growth in the long-run. Also Wang (2006) and Han (2004) using data periods of 1953-2002 and 1978-2000 respectively found evidence of bidirectional causality between energy consumption and economic growth for the People's Republic of China.

Brian et al (2007) examined the causal relationship between energy consumption and economic growth in selected Caribbean countries from 1971 to 2002 using a Granger causality test and Bayesian Vector Autoregressive technique. In their study they found that in the short-run there existed an evidence of bi-directional Granger causality from energy consumption to real gross domestic product per capita. In a study by Apergis and Payne (2009, 2010) for a panel of eleven (11) countries of the commonwealth of independent states, an evidence of bi-directional relationship between energy consumption and growth of real output was found in the long-run.

Lee et al (2008) used a panel error correction model to examine the short-run and long-run causality between energy consumption and economic growth for twenty-two (22) OECD countries. Their results show a bidirectional relationship between energy consumption, capital stock and GDP. Ebohon (1996) used the granger causality test to analyze the causal relationship between energy consumption and economic growth for Nigeria and Tanzania and found evidence of bidirectional causality between energy consumption and economic growth for both countries. Also Akinlo (2008) in his study for eleven Sub-Saharan African countries found evidence of bidirectional causality between energy consumption and economic growth for Gambia, Ghana and Senegal. The result obtained by Ebohon (1996) is opposite to results obtained by Wolde-Rufael (2006) and Gbadeho and Chinedu (2009) for Nigeria. Chali et al (2010), using panel data techniques investigated the long-run relationship between energy consumption and GDP for a panel of nineteen (19) African countries (COMESA) for the period 1980-2005. The study found that a bidirectional relationship between GDP and energy consumption exists in the long-run.

The implication of this hypothesis is that energy consumption and economic growth are complementary and that an increase in energy consumption stimulates economic growth while economic growth stimulates energy consumption.

3.2.3.4 Neutrality Hypothesis

Using annual data from 1947 to 1997 for USA, Yu and Hwang (1984) found evidence of no causality between energy consumption and GNP. Erol and Yu (1987) also in a study on the causality between energy consumption and economic growth concluded that there is no causality between energy consumption and GNP for USA. Also in a multi-country study by Yu and Choi (1985) on the causal relationship between energy consumption and economic growth, evidence of no causation between energy consumption and economic growth was found for USA, UK and Poland.

Wolde-Rufael (2006) using Toda and Yamamoto's granger causality test for seventeen Africa countries for the period 1971-2001 found no causation in the case of Benin, Congo, Kenya, Senegal, South Africa, Sudan, Togo, Tunisia and Zimbabwe. Akinlo (2008) confirmed the case for Kenya and Togo. The results obtained for Senegal, Sudan, Zimbabwe and Congo is opposite to that reached by Akinlo (2008). Also for Nigeria, Cameroon, Cote D'Ivoire, Kenya and Togo Akinlo (2008) obtained results of no causality between energy consumption and economic growth. Akinlo's finding for Nigeria contradicts that reached by Wolde-Rufael (2006).

The conclusions reached from these studies imply that energy consumption is neutral to economic growth. Similarly, economic growth is neutral to energy consumption.

3.2.3.5 Country-Specific Results

From the above empirical studies it is clear that investigations into the energy-economic growth nexus have yielded mixed results due to different estimation techniques used, choice of the data period and the level of development of the country being studied. Lin (2003) covering the period of 1978-2001 concluded that there is unidirectional causality running from economic growth to energy (electricity) consumption for China. However, Lam and Shiu (2004) using the period of 1971-

2000 obtained a unidirectional causality from energy consumption to economic growth. Also using sample or data periods 1953-2002 and 1978-2000 for Wang (2006) and Han (2004) respectively, both studies found a bidirectional relationship between energy consumption and economic growth for China.

Also in South Korea Wankeun and Kihoon (2004) using the data period 1981-2000 obtained a unidirectional causality running from income to energy consumption. However, Oh and Lee (2004) using the data period 1970-1999 obtained a bidirectional causality result between energy consumption and economic growth. However, Lee (2005) using the data period 1975-2001 obtained a unidirectional causality running from energy consumption to economic growth.

Yu and Choi (1985) using Sims and Granger causality tests obtained a unidirectional causality from GNP to energy consumption whiles Masih and Masih (1997) using a Johansen multiple cointegration and error correction models obtained a bidirectional causality between energy use and GNP for South Korea. Also Soytas and Sari (2003) using the Johansen multiple cointegration and VECM obtained a unidirectional causality running from GDP to energy consumption while Oh and Lee (2004) found a long-run bidirectional causal relationship between energy and GDP and a short-run unidirectional causality running from energy to GDP for South Korea.

In Singapore Masih and Masih (1996) used the sample 1955-1990 and obtained result of no causality between energy consumption and economic growth. However, Glasure and Lee (1997) used the sample 1961-1990 and obtained result of bidirectional causality between energy consumption and economic growth. Also Lee (2005) using the data period 1975-2001 obtained result of unidirectional causality running from energy consumption to economic growth.

In the Philippines Fatai et al (2004) used Toda and Yomamoto Granger causality test and obtained result of bidirectional causality between energy consumption and economic growth. However, Lee (2005) using Full-Modified OLS obtained result of unidirectional causality running from energy consumption to economic growth. Also Masih and Masih using standard Granger Causality test obtained result of no causality between energy consumption and economic growth.

In Sri Lanka, Morimoto and Hope (2004) using the sample 1960-1998 obtained a bidirectional relationship between energy consumption and economic growth. However, Masih and Masih (1998) and Lee (2005) used the data periods 1955-1991 and 1975-2001 respectively and obtained result of unidirectional causality from energy consumption to economic growth.

In India, Asafu-Adjaye (2000) using the data period 1973-1995 obtained result of unidirectional causality running from energy consumption to economic growth while Paul and Bhattacharya (2004) using the data period 1950-1996 obtained a bidirectional causal relationship between energy consumption and economic growth.

In Indonesia, Soytas and Sari (2003) using the sample 1950-1992 obtained no causal relationship between energy consumption and economic growth while Asafu-Adjaye (2000) obtained result of unidirectional causality running from energy consumption to economic growth using the data period 1973-1995.

In Thailand, while Asafu-Adjaye (2000) using the sample 1973-1995 obtained bidirectional causality between energy consumption and economic growth, Lee (2005) using the sample 1975-2001 obtained a unidirectional causality running from energy consumption to economic growth.

In Turkey, while Soytas and Sari (2003) using the sample 1950-1992 obtained result of unidirectional causality from energy consumption to economic growth, Kees

(2007) using the sample 1970-2003 obtained a unidirectional causality running from economic growth to energy consumption.

In Malaysia, while Masih and Masih (1996) obtained no causal relationship between energy consumption and economic growth using the sample 1955-1990, Lee (2005) using the sample 1975-2001 obtained a unidirectional causal relationship running from energy consumption to economic growth.

Also in Pakistan, while Masih and Masih (1996) obtained a bidirectional causality between energy consumption and economic growth using the sample period 1955-1990. Lee (2005) using the sample period 1975-2001 obtained unidirectional causality running from energy consumption to economic growth.

In Africa the story is not different. Various studies done in the same country have obtained varying results. Ebohon (1996) using granger causality test found evidence of bidirectional causality between energy consumption and economic growth for Tanzania and Nigeria. However, Gbadeho and Chinedu (2009) using multivariate cointegration technique found evidence of unidirectional causality running from energy consumption to economic growth for Nigeria.

In Ghana, Twerefo et al (2008) and Wolde-Rafael (2006) using different estimation techniques and sample sizes, however, reached the same conclusion that economic growth drives energy consumption. Lee (2005), however, using panel estimation techniques found evidence of unidirectional causality from energy consumption to economic growth for eighteen developing countries including Ghana. Also Akinlo (2008) using the Full-Modified OLS obtained a bidirectional causality between energy consumption and economic growth.

In Congo, Sudan and Zimbabwe while Wolde-Rufael (2006) used the Toda and Yomamoto Granger causality to reach a no causal relationship between energy consumption and economic growth, Akinlo (2008) used Full-Modified OLS to obtain a unidirectional causality running from economic growth to energy consumption.

Also in Senegal while Wolde-Rufael (2006) found no causal relationship between energy consumption and economic growth, Akinlo (2008) found evidence of bidirectional causality between energy consumption and economic growth.

Alternatively, in Cameroon, while Wolde-Rufael obtained a unidirectional causality from energy consumption to economic growth, Akinlo (2008) found no causal relationship between energy consumption and economic growth.

3.4 Conclusion

From the aforementioned empirical literature, it is evident that social, demographic and economic factors influence domestic demand for electricity. These include, gross domestic product, population growth, urbanization growth, electricity prices, prices of substitutes of electricity, weather, industrial efficiencies, structural changes in the industrial sector, and industrial growth. Also the price elasticity of demand for electricity is much larger in the long-run than in the short-run for all consumer classes. This is also the case for the income elasticity of demand for electricity. With regard to energy consumption-economic growth nexus it is evident that results provided by various studies have been mixed for countries due mainly to different estimation techniques, different sample sizes used and the level of development of the country.

CHAPTER FOUR

METHODOLOGY

4.0 Introduction

This section discusses the method of estimation used to achieve the stated objectives. Generally this section is divided into two: theoretical and empirical framework.

4.1 Theoretical Framework

Many growth models have been developed in the literature to explain the main underlying factors responsible for the long-run growth of an economy. The Solow model is among the popular pioneering growth theories that were developed to explain the long-run growth determinants of economies (Solow, 1956). This model is also known as the exogenous growth theory. This is because the model assumes that technology which explains the long-run growth of output per capita is exogenously determined.

With the assumptions of diminishing returns to capital and labour, constant savings rate and constant returns to scale, the implication of the model is that a state of stationarity will be reached when net investment and economic growth come to a halt. Thus, due to the assumption of diminishing returns to capital and labour, as more capital is employed its contribution to output increases initially and diminishes. As a result, growth of output increases, diminishes and remains stagnant. A major weakness of this model is that, the model fails to explain what determines technological progress which explains the long-run growth of output per capita. The basic Solow model assumes a production function of the form below:

$$Y = Af\left(K, L\right) \tag{4.0}$$

Where Y is real aggregate output measured by gross domestic product

A is technological progress which is assumed to be fixed

K is units of capital measured in machine hours

L is units of labour measured in man hours

From the above production function, output is a function of capital and labour with technological progress assumed to be constant. Thus, the classical economist did not view energy as an input entering into the production process. However, energy was seen as an intermediate input. To explain this model further, the neoclassical economists argued that the only drive of continuing economic growth is through technological progress. However, the model fails to explain how improvements in technology will come about. They also assume technology to be fixed. Thus, both the classical and neoclassical economists did not recognize energy as a factor of production in the production process.

A more recent model is the endogenous growth model developed by Romar (1986). This model was developed as a reaction to the flaw of the neoclassical growth theory. The endogenous theory explains the long-run growth by endogenizing technological change. The basic assumptions of the model include the following:

- Increasing returns to scale
- Human capital and production of new technologies are important for long-run growth
- Private investment in research and development is the most important source of technological progress.

According to the new growth theory, increasing level of savings and capital formation will lead to huge investment in human capital and research and development. Thus, so long as an economy does not run out of new ideas or technological advancement, the model predicts an explosive growth for an economy. The general production function postulated by Romar is of the form:

$$Y = A(R)F(R_i, K_i, L_i) \qquad (4.1)$$

Where;

Y is real aggregate output

A is public stock of knowledge from research and development

R is technology prevalent at time t

K is units of capital stock

L is units of labour

i is for firms

From the above output function, output is a function of public stock of knowledge from research and development, technology prevalent at time t, units of capital and unit of labour. Thus, in contrast to neoclassical and classical output function, the new growth output function treats technological knowledge as a form of capital that is accumulated via research and development and other knowledge creating process with some spill over benefits to the economy.

Technological progress is the acquisition of new ideas. By augmenting the production function with new ideas, the returns to scale tend to be increasing rather than been constant. Thus, Romar sees new technology as the ultimate force that underlies the long-run growth, which is determined by investment into research technology. That is investment into research technology is taken as an endogenous factor.

From the above reasoning, the new growth production function is reformulated into the form below:

$$Y = F(R, K, L) \tag{4.2}$$

Thus, output is a function of technology based on investment in research technology (R), stock of capital (K) and stock of labour (L). The technology referred herein this production function includes such things as plants, machinery etc. These technologies are energy driven. Without adequate stock of energy, these technologies are useless. According to the law of thermodynamics, "no production process can be driven without energy conversion". It is important to reiterate here that while energy is not the sole determinant of technology, it is a very crucial factor which ensures that technology is being utilized[18]. That is conversion of energy in its raw state into useful forms is highly technology oriented.

From the above reasoning technology can be seen as been closely related to energy. That is energy enters into the production function as a separate input which firms and individuals have specific demand for. That is;

$$Y = F(E, K, L) \tag{4.3a}$$

Where Y is real aggregate output

E is energy

K is the stock of capital

L is the stock of labour

In the analysis of demand for a particular energy type, it has widely been argued that demand for a particular energy type should be analysed in the context or framework of energy market. This is so because, the factor which appears in the production function and for which firms and individuals has specific demand for is

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[18] Gbadeho O.O., & Chinedu O., (2009)

"energy". In this approach each energy type is reduced to a common measure of "energy" to analyze the aggregate behaviour. However, this approach has some measurement problems inherent in converting each energy type to a common "energy currency". This approach ignores the fact that the separate energy type has varying conversion efficiencies depending on their application. That is the difficulty in getting any meaningful measure of energy is due to the varying technological efficiencies and the wide ranges of substitutability among the different energy types in their various applications. The use of the energy approach therefore has a doubtful validity. Thus, it is not an appropriate tool for analyzing demand for a particular type of energy (Baxter and Rees, 1968).

The most appropriate approach, which is the one adopted in this study, is to treat each energy type, as a separate input entering into the production function. The implication of this is that firms and individuals have separate demand functions for each energy type. This approach avoids certain practical and conceptual disadvantages associated with aggregate "energy demand analysis approach.

In Ghana, there are three basic sources of energy. These are petroleum, biomass and electricity. Disaggregating total energy into its parts, the output function can be reformulated into a form like;

$$Y = F(B, P, EC, K, L) \qquad (4.3b)$$

The above equation says that output is a function of biomass (B), petroleum (P), electricity (EC), capital (K) and labour (L). Electricity demand studies have been considered within the context of household/firm production theory. Within this framework the household/firm combines electricity with capital to produce a composite energy demand commodity whose output is determined by the quantity of electricity bought and the stock of capital appliances (Narayan and Smyth, 2005).

With a straight forward application from the theory of demand for input and following from Baxter and Rees (1968), a Cobb-Douglas production function, which is defined on the inputs of biomass, petroleum, electricity, capital and labour, is postulated.

$$Q = \alpha_0 X_1^{\alpha_1} X_2^{\alpha_2} \ldots X_k^{\alpha_k} \quad (4.4)$$

Where Q is real aggregate output

$X_j \left(j = 1,2,\ldots k \right)$ are the relevant inputs

$\alpha_j \left(j = 0,1,2,\ldots k \right)$ are the corresponding parameters

It is assumed in the theory of the firm that individual firms seeks to minimize total costs of production for any output given by

$$C = p_1 X_1 + p_2 X_2 + \ldots p_k X_k \quad (4.5)$$

Where C is the total cost and $p_j \left(j = 1,2,\ldots k \right)$ are the input prices

Minimizing equation 4.5 subject to 4.4 yields the following equations;

$$L = P_1 X_1 + P_2 X_2 + \ldots + P_K X_K + \lambda \left(Q - \alpha_0 X_1^{\alpha_1} X_2^{\alpha_2} \ldots X_K^{\alpha_K} \right) \quad (4.6a)$$

$$P_1 - \lambda \alpha_1 \alpha_0 X_1^{\alpha_1 - 1} X_2^{\alpha_2} \ldots X_K^{\alpha_K} = 0 \quad (4.6b)$$

$$P_2 - \lambda \alpha_2 \alpha_0 X_1^{\alpha_1} X_2^{\alpha_2 - 1} \ldots X_K^{\alpha_K} = 0 \quad (4.6c)$$

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$$P_K - \lambda \alpha_K \alpha_0 X_1^{\alpha_1} X_2^{\alpha_2} \ldots X_K^{\alpha_K - 1} = 0 \quad (4.6d)$$

$$Q - \lambda \alpha_0 X_1^{\alpha_1} X_2^{\alpha_2} \ldots X_K^{\alpha_K} = 0 \quad (4.6e)$$

Where λ is the langrangean multiplier, this is a system of (K+1) equations in (K+1) unknowns, namely $X_1, X_2, \ldots X_K$ and λ. Letting electricity to be the Kth input and solving the equations above for X_K , we obtain the demand function for electricity as

$$X_K = \beta_0 P_1^{\beta_1} P_2^{\beta_2} \ldots P_K^{\beta_K} Q^{\beta_{K+1}} \quad (4.6f)$$

Thus, electricity demand is an exponential function of the Kth input prices, prices of substitutes and output where $\beta_j\left(j=0,1,2,.....k+1\right)$ are the parameters of the relationship representing combinations of the $\alpha_j\left(j=0,1,2,...k\right)$. Taking the natural logs of equation 4.6f gives a new equation of the form:

$$\ln X_K = \beta_0 + \beta_1 \ln P_1 + \beta_2 \ln P_2 + ...\beta_K \ln P_K + \beta_{K+1} \ln Q \qquad (4.6g)$$

Letting

$X_K = EC,$ (Electricity consumption)

$P_1 = B_P,$ (Price of Biomass)

$P_2 = W$ (Price of labour)

$P_3 = R$ (Price of capital)

$P_4 = PP$ (Price of petroleum)

$P_5 = EP$ (Electricity price)

Equation 4.6g becomes

$$\ln EC = \beta_0 + \beta_1 \ln B_P + \beta_2 \ln W + \beta_3 \ln R + \beta_4 \ln PP + \beta_5 \ln EP + \beta_6 \ln Q \qquad (4.6h)$$

Given that electricity is the main product; all other prices could be treated as price of related goods. This reduces equation 4.6h into 4.6i;

$$\ln EC = \beta_0 + \beta_1 PR + \beta_2 \ln EP + \beta_3 \ln Q \qquad (4.6i)$$

Equation 4.6i says that electricity demand is a function of the price of related goods, price of electricity and output (income).

4.2 Empirical Framework

Following from the theoretical specification in equation (4.6i), the empirical specification of the model in this study begins with a standard demand model that relates electricity demand to some specified factors. The empirical model in this study is of the form:

$$EC_t = X_t \beta^* + \xi_t \qquad (4.7)$$

Where EC is the amount of electricity consumed which is expressed as a function of a vector of explanatory variables X_t. $\beta *$ represents the corresponding coefficients and ζ_t is the white noise stochastic term.

The inclusion of variables in the vector X is based on what has been largely used in the literature and their relevance to the Ghanaian economy. For instance, Lin (2003) modelled electricity demand as a function of electricity prices, prices of substitutes, population, real gross domestic product, industrial efficiency and structural changes in industries. Amusa et al (2009) modelled electricity demand as a function of electricity prices and real income. Lyman (1973) modelled electricity demand as a function of price of electricity, price of gas, index of other prices, vector of economic and demographic variables and a vector of climate variables. Also Issa and Bataineh (2010) modelled electricity demand as a function of price of electricity, real GDP, degree of urbanisation, and industrial efficiency. Thus, according to the literature variables normally included in models of electricity demand include: electricity price, price of fuel alternatives, weather, population, degree of urbanization, prices of appliances, industrial output and industrial efficiencies and a measure of economic activity.

All of these variables were initially considered for inclusion in the vector X; however, due to some reasons explained below some of them were dropped from the model. Specifically, this study included six variables in the vector of X: price of electricity, population, industrial output, industrial efficiencies, real per capita GDP (measure of economic activity) and degree of urbanization. In the paragraphs that follow I discuss the transmission mechanism and the reasons for the exclusion and inclusion of some variables.

Weather is an important variable in modelling electricity demand most especially when the focus is on the residential sector. During cold days, electricity is demanded for the purposes of heating. Thus, with large household size, this implies that more electricity would be needed for heating. Also during hot days, more electricity is needed for cooling purposes. That is with large temperature variation, weather is expected to have an increasing influence on aggregate domestic consumption of electricity. However, when residential sector constitutes a small share of national consumption of electricity, weather tends to have less explanatory power. As noted by Pouris (1987), in models that use annual data from countries where residential sector accounts for a small share of total electricity consumed, changes in temperature tends to exhibit less explanatory power. Also argued by Diabi (1998), when temperature exhibits less variation between years, it will matter less in terms of explaining variability in electricity demand. Ghana's daily load shape is not volatile as the load shape of countries in the temperate and polar regions.

"Ghana's equatorial position and tropical climate have resulted in minimal seasonal variations in daylight and temperature relative to polar locations such as Norway or South Africa. As a result there is minimal seasonality in electricity demand". (PSEC & GRIDCo, 2010 report). Based on these grounds the weather variable is excluded from the model.

Electricity price is an important factor that affects electricity demand. According to the normal theory of demand, changes in price tend to have a decreasing effect on the demand for the commodity in question and vice versa. Thus, as the price of electricity increases consumers of electricity reduces their consumption of electricity. Contrary, as the price of electricity decreases, consumers of electricity increases their consumption of electricity. This is because at higher prices there is substitution away from electricity to other energy alternatives while at lower prices substitution is in favour of electricity. In Ghana, the price of electricity has been administratively kept lower than the long-run marginal cost of electricity production. Compared to the Sub-Saharan African average, Ghana's tariff is lower by US$ 0.13 per kilowatt-hour and is amongst the lowest in West Africa. This has resulted in the general unsatisfactory service of the utility companies. Despite this, electricity price is very crucial in terms of explaining electricity demand in the country. However, given the sample period considered, data on electricity price is unavailable. Thus, the electricity price variable is barred mainly due to data unavailability. Also in the literature, the average price of electricity has been found to have insignificant effect on demand for electricity at the aggregate level. Thus, at the aggregate or national level, electricity price is not an important drive of aggregate consumption of electricity.

Price of substitutes is also another vital factor when explaining electricity demand. In Ghana, kerosene, natural gas, biomass and petroleum are the major alternatives used. As the price of these substitutes increases relative to the price of electricity, consumers of other alternatives will see electricity as been cheaper compared to the other alternatives. This implies that, there will be a switch away from these alternatives towards the consumption of electricity, thereby increasing the demand for it. Conversely, when the price of electricity increases relative to the price of other substitutes, there will be a substitution away from the consumption of electricity towards the consumption of other alternative source of electric power. In Ghana, the major fuel surrogate for electricity is petrol/oil which provides about 30%

of total energy consumption, supports about 85% of electricity production in the country and provides about 90% of the transport sector energy source. Ghana's electricity as at 2009 was 60% hydro driven and 40% thermal driven. Thermal generation mainly thrives on petro/oil with major generation plants operated at the hydro sites also petrol/oil driven. As a result, it is reasonable to expect that significant long-term changes in the price of petrol will partially be reflected in prices levied on end users of electricity. As a result this variable is also excluded from the model for possible problems of muliticollinearity.

Electricity is an important input in most activities and thus, makes demand for electricity to be positively and highly correlated with per capita GDP, which is a measure of economic activity. Growth in real per capita GDP implies increase in household disposable income which means increase purchase of electric appliances. The effect is increase in residential consumption of electricity due to increase usage of electricity-consuming appliances. Also growth in real per capita GDP implies increase in investment expenditures. These investment expenditures are mostly in the form of machines and equipment which are energy driven. Thus, as the purchase of equipments and machines increases industrial use of electricity surges thereby affecting aggregate domestic consumption of electricity positively. Thus, growth in real per capita GDP is expected to have a positive impact on electricity demand. Following from Amusa et al (2008) and Lyman (1973) per capita real GDP which measures economic activities is included as an explanatory variable in modelling electricity demand for Ghana.

Energy efficiency refers to the activity that can be produced with a given amount of energy. Energy efficiency[19] improves when a given level of output or

[19] A decrease in energy intensity is a surrogate for energy efficiency.

service is provided with reduced amount of energy inputs. Thus, as industrial efficiency improves, industrial consumption of electricity reduces. Given that industrial consumption of electricity constitute a significant share of national aggregate of electricity consumption; this will in the end reduce national aggregate consumption of electricity. In Ghana, while industrial output grew by 4.7% in 2002, industries' electricity intensity reduced to 3517.595 KWh\$. In the same year while real GDP grew by 4.5%, annual electricity consumption decreased by 5.4%. Also in 2003, while annual real GDP grew by 5.2% and industrial output growth by 5.1%, industries' electricity intensity and annual electricity consumption both decreased to 1852.577 KWh\$ and by 26% respectively[20]. This suggests that energy conservation measures have produced significant positive results. Following from Lin (2003) and Issa and Bataineh (2010), efficiency improvements in the industrial sector which is measured as the ratio of value-added by industry to electricity consumed by industry is considered as another variable in the estimation of electricity demand. As technologies improve and energy conservation measures are introduced in industries, this ratio is expected to have a negative impact on electricity demand.

Urbanization rate is the proportion of the total population that live in urban areas. Urbanisation is expected to increase electricity consumption for two reasons. First urbanisation implies greater access to electricity, since households can be easily connected to the grid. Also consumers who already had access to electricity before moving are likely to increase their consumption once they are in an urban setting. In Ghana, the urban areas have better access and connectivity to electricity. In 2008, while 85% of the urban areas had access to electricity only 23% of the rural areas had access to electricity. Also urban areas have higher per capita incomes since they have

[20] EnerDATA and State of the Ghanaian Economy

been the focal point of economic growth. Higher incomes lead to increased ownership of electricity-consuming household appliances thereby driving electricity usage. Accra, Kumasi, and Tema (AKT) are the major urban cities in Ghana that largely drives electricity consumption. In 2009 these urban sectors accounted for 52% of national peak demand and an average of over 50% of energy demand. Tema recorded the highest (peak demand growth of more than 60% and energy consumption growth of more than 159%) followed by Accra (peak demand growth of 40% and energy consumption growth of 90%) and Kumasi (peak demand growth of 40% and energy consumption growth of 65%).[21] This indicates that the degree of urbanisation is a factor that drives electricity consumption especially in Ghana. This is expected to have a positive impact on electricity demand for Ghana. Thus, following from Holtedahl and Joutz (200) I include urbanisation as another explanatory variable to capture the effects demorgraphy on electricity demand.

Population refers to the total number of people living in a geographical area at a point in time. This comprises both indigenous and foreigners. Increase in population implies that there will be more need for ironing, cooking, heating, cooling, and lightening. Thus, increase in population is expected to have a positive effect on electricity demand. Following from Lin (2003) this thesis includes population as another explanatory variable.

Structural changes in the economy away from more energy intensive industries toward less energy intensive industries such as the service and agricultural sectors have significant impact on the growth of electricity demand in any economy. Given that the service and agricultural sectors are less energy intensive, a structural change in an economy towards these sectors will lead to a fall in the growth of

[21] PSEC & GDRIDCo (2010): Power Reliability Assessment

electricity demand. In Ghana, the structure of the economy shows a shift towards the service sector which is less energy intensive. For instance, between 2000 and 2008, even although the real per capita GDP grew at 5.5%, electricity demand grew only at 1.2%. Following from Lin (2003) and Zuresh and Peter (2007) I include structural changes in the economy for which the industry share of GDP is used as a proxy. This variable is expected to have a positive relationship with electricity demand. Thus, a fall in industries' share of GDP would mean less electricity would be used by the industrial sector, the most energy intensive sector. This further implies that in terms of the composition of aggregate electricity consumption there will be a shift away from the more energy intensive sector (industrial sector) to the less energy intensive sectors (service and agricultural sector) leading to an overall decrease in electricity usage and vice versa.

Therefore following the studies by Lyman (1973), Lin (2003), and Amusa et al (2009), the electricity demand equation to be estimated in this study is specified in the form below;

$$\ln EC_t = \beta_0 + \beta_1 \ln EF_t + \beta_2 \ln Y_t + \beta_3 \ln V_t + \beta_4 \ln P_t + \beta_5 \ln U_t + \varepsilon_t \qquad (4.7a)$$

Where EC is total domestic consumption of electricity

EF is efficiency improvements in the industrial sector

Y real per capita GDP

V is structural changes in the economy

U is growth in urban population

P is population

This study modifies the works by Amusa et al (2009), Lin (2003) and Lyman (1973) by including the following variables; industrial efficiency, industrial output growth, degree of urbanisation and real per capita GDP. The model deviates from Amusa et al and Lin since it does not provide estimates of price and cross price elasticity. However, given that at the aggregate level, average electricity price does not explain aggregate electricity demand as argued in the literature (see Fisher and Kaysen, 19), the omission of the price variables from the model is not expected to affect the robustness of the model estimated in this work.

4.3 Data sources

This study employs annual data series from 1975 to 2008 to estimate electricity demand. The choice of this sample period is largely informed by two factors. First, to arrive at robust estimates of coefficients, econometric techniques require data points of not less than thirty (30) years. Lastly, this sample period was chosen mainly because of data availability within the considered sample. Information on total domestic electricity consumption and industrial efficiencies were obtained from EnerData Global Energy and CO_2 Data Research Services while information on per capita real GDP, industries' share of GDP and urbanization rate was sourced from Africa Development Indicators (ADI). Lastly, the total population variable was sourced from the International Financial Statistics (IFS). Secondary, the study conducts causality test between electricity consumption and economic growth using the sample period 1971 to 2008. In analysing the causal relationship between energy and economic growth, different data points, varying estimation techniques and the level of development of the country have been cited as the reasons for the mixed results in the literature. In this study I use different data points and econometric technique from that used by Twerefo et al (2008) and Akinlo (2008) to see if the results obtained validate or invalidate their results.

4.4 Econometric Estimation Technique

In this section of the study, I present a detail description of the econometric techniques adopted in the study. Specifically, a description of the ARDL model and Toda and Yomamoto Granger causality test is provided.

4.4.1 Stationarity and Unit Root Problem

Many macroeconomic time series contain unit roots (Nelson and Plosser, 1982). Testing for unit root in time series is therefore important since non stationary regressors invalidate many results and thus require special treatment. Several unit root tests exist in the literature. These include Dickey-Fuller test, Augmented Dickey-Fuller test, Phillip-Perron test, Kwiatkowski et al test etc. The ADF test procedure is based on the OLS regression below

$$\Delta z_t = \beta_0 + \alpha_0 T + \alpha_1 z_{t-1} + \sum_{i=1}^{k} \beta_1 \Delta z_{t-i} + \varepsilon_t \ldots\ldots\ldots\ldots\ldots (4.8)$$

Where T is a linear trend, Z is the variable that is being tested for unit root, Δ is the first difference operator and ε_t is the Gaussian white noise term and K is chosen to achieve white noise residuals. To examine the unit root properties of the series, this study will adopt the ADF and PP test statistic. The optimal lag length will be determined using the Akaike Information Criterion which is appropriate for small sample sizes.

4.4.2 Cointegration Analysis

Cointegration is the existence of a long-run equilibrium relationship between series. The existence of cointegration implies that short-term disturbances that occur will not distort the long-run equilibrium relation that exists between variables.

Basically the analysis of cointegration has been carried out in the literature using three different approaches. These are the procedures of Engle and Granger (1987), the procedure of Johansen and Juselius (Johansen and Juselius 1990, Johansen 1995) and the latest the Autoregressive Distributed Lag Model (ARDL) Bounds testing procedure of cointegration (Pesaran et al, 2001).

The Engle and Granger approach uses the residuals from the cointegration regression which is the linear combination between the series. If the linear combination between the series is stationary then the series involved are said to be cointegrated. According to the Engle and Granger Representation theorem, if two series say X and Y are cointegrated then they are generated by error correction model. Conversely if X and Y are generated by an error correction model, then they are cointegrated. The major problem with this approach is that it does not provide any scope of dealing with more than two variables. Thus, the approach is more appropriate when there is one cointegrating vector between two variables. Given that this study has more than two variables there is the possibility of having more than one cointegrating vector and therefore may not be appropriate in this study.

As a solution to this problem an alternative approach called the Johansen technique was proposed. This approach is based on the vector autoregressive framework, which is a dynamic model involving a number of time series. Sims (1980) argues that with simultaneity among variables, the process of classifying variables as endogenous or exogenous involves arbitrary decisions. In practice all variables should be given equal consideration and so all should be treated as endogenous. The application of this approach requires a pre-test of order of integration. Thus, all variables will have to be integrated of order (1). This suggests that the Johansen approach to cointegration is not appropriate when there is a mix order of integration.

For example, the mixture of I (1) and I (0) variables would not be possible under this procedure. Also while able to deal with multivariate cointegration in large systems, the Johansen method is much more complex and suffers from the problem that the asymptotic critical values of the test statistics can result in incorrect inference in small samples like the one used in this study.

Given the above weakness of the above mentioned cointegration techniques, this study is justified in applying a technique that is able to overcome the above stated weaknesses of the Engle and Granger (1987) and Johansen and Juselius (1990). Hence the study adopts the Autoregressive Distributed Lag Model (ARDL) Bound testing to cointegration developed by Pesaran and Shin (1999) and later extended by Pesaran et al (2001). The ARDL bounds testing approach compared to the other approaches of cointegration has several distinct advantages. One of the main advantages of the ARDL approach in contrast to the Engle and Granger (1981) and Johansen approach (1990) is that the ARDL approach does not impose any restriction on the order of integration of the variables considered. Thus, the ARDL approach permits to test for cointegration regardless of whether the variables are all I (1) or I (0) or a mixture of the two.

The next important strength of the bounds testing approach lies in the fact that while the other two approaches are sensitive to the values of nuisance parameters in finite samples, the ARDL bounds approach is not sensitive to the size of the sample, therefore, making its small sample properties more superior to the multivariate cointegration. Thus, the ARDL approach is more appropriate when dealing with models with small sample.

The next thing worth talking about is the fact that the ARDL approach is known to provide unbiased long-run estimates even when some of the variables are endogenous. Narayan (2005) and Odhianbo (2008) as quoted in Amusa et al (2009) demonstrates that even when some of the independent variables are endogenous, the bounds testing approach generally provides unbiased long-run estimates and valid t-statistics.

As a result of these strengths associated with the adoption of ARDL bounds testing approach, the method has widely been used in energy demand and other studies. (See; Squalli and Wilson, 2006, Wolde-Rafael, 2005 and Amusa et al, 2009). Using this approach electricity demand is expressed as a function of the lagged values of itself and the current and lagged values of other explanatory variables in the model. The inclusion of the lagged value of the dependent variable is to account for the sluggish adjustment process often associated with the response of energy consumption to changes in explanatory variables (Amusa et al, 2009).

This study adopts the ARDL bounds testing approach to test for the existence of a long-run relationship between electricity consumption and the other explanatory variables. The ARDL approach is really an attempt to match the unknown data generating process with a correctly specified model (Hendry et al, 1984) as quoted in Amusa et al (2009). The formal ARDL model is of the form;

$$\phi(L,P)y_t = \sum_{i=1}^{k} \beta_i(L,q_i)x_{it} + \delta' w_t + u_t \qquad (4.81)$$

Where

$$\phi(L,P) = 1 - \phi_1 L - \phi_2 L^2 - \ldots - \phi_p L^p,\; p = 0,1,\ldots,m$$

$$\beta_i(L_{i,}q_i) = \beta_{i0} + \beta_{i1}L + \ldots + \beta_{iq_i}L^{q_i},\; i = 1,2,\ldots k,\; q_i = 0,1,\ldots,m$$

L is a lag operator; $Ly_t = y_{t-1}$

W_t is an S x 1 vector of deterministic variables such as time trend, seasonal dummies, intercept and variables with fixed lags. X_t is an n x k vector of explanatory variables.

The long-run coefficients for the response of Y_t to a unit change in X_{it} are estimated by

$$\hat{\phi}_i = \frac{\hat{\beta}_i(1,\hat{q}_i)}{\hat{\phi}(1,\hat{p})} = \frac{\hat{\beta}_{i0} + \hat{\beta}_{i1} + \ldots + \beta_{iq_i}}{1 - \hat{\phi}_1 - \hat{\phi}_2 - \ldots \hat{\phi}_p}, i = 1,2,\ldots,k$$

Where $\hat{p}$ and $\hat{q}_i$, i=1, 2... k are the estimated values of p and q_i, i=1, 2,..., k. Similarly, the long-run coefficients associated with the deterministic/exogenous variables with fixed lags are estimated by;

$$\hat{\psi} = \frac{\hat{\delta}(\hat{p}\ ,\hat{q}_1,\hat{q}_2,\ldots,\hat{q}_k)}{1 - \hat{\phi}_1 - \hat{\phi}_2 - \ldots - \hat{\phi}_p}$$

Where $\hat{\delta}(\hat{p}\ ,\hat{q}_1,\hat{q}_2,\ldots,\hat{q}_k)$ denotes the OLS estimate of δ for the selected ARDL model. In order to test for cointegration we need to estimate an unrestricted error correction model of the form below.

$$\Delta\ln EC_t = \alpha_{0ec} + \sum_{i=1}^{a}\beta_{iec}\Delta\ln EC_{t-i} + \sum_{j=1}^{b}\delta_{jec}\Delta\ln EF_{t-j} + \sum_{k=1}^{c}\lambda_{kec}\Delta\ln Y_{t-k} + \sum_{l=1}^{d}\sigma_{lec}\Delta\ln V_{t-l} +$$

$$\sum_{m=1}^{e}\eta_{mec}\Delta\ln U_{t-m} + \varphi_{1ec}\ln EC_{t-1} + \varphi_{2ec}\ln EF_{t-1} + \varphi_{3ec}\ln Y_{t-1} + \varphi_{4ec}\ln V_{t-1} + \varphi_{5ec}\ln U_{t-1} + e_{1t}$$
(4.82a)

Where the parameters of the difference variables are the short-run dynamics; the coefficient of the lag level variables are the long-run multipliers and e is the white noise term. However, to obtain the direction of the cointegration I normalised each of the variable as a dependent variable and estimate the following unrestricted error correction models.

$$\Delta\ln EF_t = \alpha_{0ef} + \sum_{i=1}^{a}\beta_{ieF}\Delta\ln EF_{t-i} + \sum_{j=1}^{b}\delta_{jef}\Delta\ln EC_{t-j} + \sum_{k=1}^{c}\lambda_{kef}\Delta\ln Y_{t-k} + \sum_{l=1}^{d}\sigma_{lef}\Delta\ln V_{t-j}$$

$$+ \sum_{m=1}^{e}\eta_{mef}\Delta\ln U_{t-m} + \varphi_{1ef}\ln EF_{t-1} + \varphi_{2ef}\ln EC_{t-1} + \varphi_{3ef}\ln Y_{t-1} + \varphi_{4ef}\ln V_{t-1} + \varphi_{5ef}\ln U_{t-1} + e_{2t}$$

(4.82b)

$$\Delta \ln Y_t = \alpha_{0y} + \sum_{i=1}^{a} \beta_{iy} \Delta \ln Y_{t-i} + \sum_{j=1}^{b} \delta_{jy} \Delta \ln EF_{t-j} + \sum_{k=1}^{c} \lambda_{ky} \Delta \ln EC_{t-k} + \sum_{l=1}^{d} \sigma_{ly} \Delta \ln V_{t-l} +$$

$$+ \sum_{m=1}^{e} \eta_{my} \Delta \ln U_{t-m} + \varphi_{1ec} \ln Y_{t-1} + \varphi_{2y} \ln EF_{t-1} + \varphi_{3y} \ln EC_{t-1} + \varphi_{4y} \ln V_{t-1} + \varphi_{5y} \ln U_{t-1} + e_{3t}$$

(4.82c)

$$\Delta \ln V_t = \alpha_{0v} + \sum_{i=1}^{a} \beta_{iv} \Delta \ln V_{t-i} + \sum_{j=1}^{b} \delta_{jv} \Delta \ln Y_{t-j} + \sum_{k=1}^{c} \lambda_{kv} \Delta \ln EF_{t-k} + \sum_{l=1}^{d} \sigma_{lv} \Delta \ln EC_{t-l} +$$

$$+ \sum_{m=1}^{e} \eta_{nv} \Delta \ln U_{t-m} + \varphi_{1v} \ln V_{t-1} + \varphi_{2v} \ln Y_{t-1} + \varphi_{3v} \ln EF_{t-1} + \varphi_{4v} \ln EC_{t-1} + \varphi_{5v} \ln U_{t-1} + e_{4t}$$

(4.82d)

$$\Delta \ln U_t = \alpha_{0v} + \sum_{i=1}^{a} \beta_{iu} \Delta \ln U_{t-i} + \sum_{j=1}^{b} \delta_{ju} \Delta \ln V_{t-j} + \sum_{k=1}^{c} \lambda_{ku} \Delta \ln Y_{t-k} + \sum_{l=1}^{d} \sigma_{lu} \Delta \ln EF_{t-l} +$$

$$+ \sum_{m=1}^{e} \eta_{nu} \Delta \ln EC_{t-m} + \varphi_{1u} \ln U_{t-1} + \varphi_{2u} \ln V_{t-1} + \varphi_{3u} \ln Y_{t-1} + \varphi_{4u} \ln EF_{t-1} + \varphi_{5u} \ln EC_{t-1} + e_{4t}$$

(4.82e)

Where the subscripts of the respective parameters represent the coefficients of the independent variables at their various lags. Due to high levels of temporal aggregations involved, it is not possible to know a priori whether for instance in equation 4.82a, lny, lnef, lnu, and lnv are the 'long-run forcing' variables for aggregate domestic electricity consumption. As a result I exclude the current values of the difference variables. This will be established when I have conducted the test of long-run relationship.

The bounds test involves three steps. The first deals with the testing of the existence of cointegration between the dependent variable and the set of explanatory variables. The test of cointegration involves restricting the coefficients of the lagged level variables to zero. The corresponding f-statistics is then compared to Pesaran et al two bound asymptotic critical values. Thus, in this work the following null hypothesis is tested.

$H_0; \varphi_{1ec} = \varphi_{2ec} = \varphi_{3ec} = \varphi_{4ec} = \varphi_{5ec} = 0$

As against an alternative hypothesis of

$H_A; \varphi_{1ec} = \varphi_{2ec} = \varphi_{3ec} = \varphi_{4ec} = \varphi_{5ec} \neq 0$

When the regressors are I (1) or I (0), there are two asymptotic critical value bounds that provide a test for the existence of cointegration: the upper bound critical value and the lower bound critical value. The upper bound assumes that the variables are I (1) while the lower bound assumes that the variables are I (0). Thus, the test provides a band of values covering all possible classifications of the variables into I (1), I (0) or mutually cointegrated. When the estimated F-Statistics exceed the upper bound we fail to accept the null of no cointegration and accept the alternative that there is cointegration. Also when the computed F-Statistics falls below the lower bound, we fail to reject the null hypothesis of no cointegration relationship. Thus, there exists no cointegrating relationship. However, when the computed F-Statistics falls within the bound the result is inconclusive and requires knowledge on the order of integration.

This study tests for the existence of cointegration for equations (4.82a), (4.82b), (4.82c), (4.82d) and (4.82e) using the following null hypothesis

$H_0; \varphi_{1ec} = \varphi_{2ec} = \varphi_{3ec} = \varphi_{4ec} = \varphi_{5ec} = 0$ ....Electricity consumption equation

$H_0; \varphi_{1ef} = \varphi_{2ef} = \varphi_{3ef} = \varphi_{4ef} = \varphi_{5ef} = 0$ ....Industrial efficiency equation

$H_0; \varphi_{1y} = \varphi_{2y} = \varphi_{3y} = \varphi_{4y} = \varphi_{5y} = 0$ .... Per capita real GDP equation

$H_0; \varphi_{1v} = \varphi_{2v} = \varphi_{3v} = \varphi_{4v} = \varphi_{5v} = 0$ ....Value added of industry equation

$H_0; \varphi_{1u} = \varphi_{2u} = \varphi_{3u} = \varphi_{4u} = \varphi_{5u} = 0$ ....degree of urbanization equation

After establishing the existence of a long-run relationship, the next step requires estimating a long-run equation such as equation (4.7a)

$$\ln EC_t = \beta_0 + \beta_1 \ln EF_t + \beta_2 \ln Y_t + \beta_3 \ln V_t + \beta_4 \ln U_t + \varepsilon_t \qquad (4.7a)$$

The estimated parameters of the explanatory variables give the long-run elasticities. To assess the impact of the explanatory variables on the dependent variable, this study will apply the standard t-test statistics or p-value to test for the level of significance of the estimated long-run parameter estimates. For example, to assess the impact of industrial efficiency on electricity consumption the parameter estimate β_1 is restricted to zero. Thus, the study test the null hypothesis of

$H_0 : \beta_1 = 0$

As against the alternative hypothesis of

$H_A : \beta_1 \neq 0$

If the test statistic is greater than the critical values, then the null hypothesis is rejected in favour of the alternative hypothesis. Thus industrial efficiency significantly affects electricity consumption. However, if the calculated test statistics is less than the critical values the null hypothesis is accepted. In this case we say that industrial efficiency does not significantly affect electricity consumption. A similar test of significance is carried on the remaining estimated long-run parameter estimates. The following null hypothesises were tested;

$H_0 : \beta_2 = 0$, $H_0 : \beta_3 = 0$, $H_0 : \beta_4 = 0$, $H_0 : \beta_5 = 0$ as against alternatives of

$H_A : \beta_2 \neq 0$, $H_A : \beta_3 \neq 0$, $H_A : \beta_4 \neq 0$, $H_A : \beta_5 \neq 0$

The final step in the ARDL bounds approach is to estimate a short-run error correction model. The error correction model associated with the ARDL

$(\hat{p}\ ,\hat{q}_1,\hat{q}_2,...,\hat{q}_k)$ model can be obtained by writing equation 4.81 in terms of the lagged levels and the first difference of Y_t, X_{it}, X_{2t}... X_{kt}, and w_t. Given that;

$$y_t = \Delta y_t + y_{t-1}$$
$$y_{t-s} = y_{t-1} - \sum_{j=1}^{s-1} \Delta y_{t-j}, s = 1,2,.., P$$

Similarly

$$w_t = \Delta w_t + w_{t-1}$$
$$x_{it} = \Delta x_{it} + x_{i,t-1}$$
$$x_{i,t-s} = x_{i,t-1} - \sum_{j=1}^{s-1} \Delta x_{i,t-j,} s = 1,2,.., q_i$$

By substituting these into 4.81, and after some rearrangements, we have an error correction model of the form;

$$\Delta y_t = \phi(1,\hat{p})EC_{t-1} + \sum_{i=1} \beta_{i0}\Delta x_{it} + \delta\Delta w_t - \sum_{j=1}^{\hat{p}-1} \phi_j^{\ *}\Delta y_{t-1} - \sum_{i=1}^{k}\sum_{j=1}^{q_i-1} \beta^*{}_{ij}\ \Delta x_{i,t-j} + u_t \text{....(4.9)}$$

Where EC_t is the error correction term defined by;

$$EC_t = y_t - \sum_{i=1}^{k} \hat{\theta}_i x_{it} - \hat{\psi}^1 w_t$$

$\phi(1,\hat{p}) = 1 - \hat{\phi}_1 - \hat{\phi}_2 - ... - \hat{\phi}_p$, measures the quantitative importance of the error correction term. The remaining coefficients $\phi_j^{\ *}$ and $\beta_{ij}^{\ *}$ relate the short-run dynamics of the model's convergence to equilibrium. These are given by;

$$\phi_1^{\ *} = \phi_{\hat{p}} + \phi_{\hat{p}-1} + ... + \phi_3 + \phi_2$$
$$\phi_2^{\ *} = \phi_{\hat{p}} + \phi_{\hat{p}-1} + ... + \phi_3$$

.

.

$$\phi_{\hat{p}-1}^{\ *} = \phi_{\hat{p}}$$

And similarly,

$$\beta_{i1}{}^{*} = \beta_{1\hat{q}i} + \beta_{i\hat{q}_{i-1}} + \ldots. + \beta_{i,3} + \beta_{i,2}$$

$$\beta_{i2}{}^{*} = \beta_{i,\hat{q}_i} + \beta_{i\hat{q}_{i-1}} + \ldots + \beta_{i,3}$$

.

.

$$\beta_i^{*}{}_{,q_{i-1}} = \beta_{i,q_i}$$

The estimates of the parameters of the error correction model are obtained from the coefficients estimates of the ARDL model using the above relations. A simplified form of the error correction model is as shown below;

$$\Delta \ln EC_t = \alpha_0 + \sum_{i=1}^{b} \delta_1 \Delta \ln EF_{t-i} + \sum_{j=1}^{c} \lambda_1 \Delta \ln Y_{t-i} + \sum_{k=1}^{d} \sigma_1 \Delta \ln V_{t-i} + \sum_{l=1}^{f} \gamma_1 \Delta \ln U_{t-i} + \pi ECT + \varepsilon_t \ldots.(4.91)$$

The coefficients of the differenced variables measure short-run elasticities while π measures the speed of adjustment of short-run deviations towards long-run equilibrium. The speed of adjustment parameter is expected to be negative. ECT is the error correction term. A test of significance on the speed of adjustment parameter is of great importance. This is so because in reality variables are not always in their long-run state and therefore the speed of adjustment parameter is a measure of disequilibrium error of variables of interest away from their long-run equilibrium. A test statistics that establishes that the speed of adjustment parameter is significantly different from zero implies that short term deviations in the economy will not distort the long-run equilibrium relationship.

4.4.3 Diagnostic Test

The adequacy of the model lies in its statistical properties reflected in diagnostic test. These include test for serial correlation, test for functional form, test for normality, test for heteroscedasticity and test for stability of the parameters in the model. To test for serial correlation I test for the null; there is no serial correlation in the model. To test for the functional form, the stated null hypothesis is that there is no functional misspecification. The test for normality tests the null hypotheses that the residuals of the model are normally distributed. The problem of heteroscedasticity is tested using the null; the residuals of the model are homoscedastic. The test of stability of the estimated model is done using the recursive cumulative sum of squares and cumulative sum proposed by Brown et al (1975). The Cumulative Sum (CUSUM) is based on the cummulative sum of the recursive residuals. This option plots the cumulative sum together with the 5% critical lines. The test finds parameter instability if the cumulative um goes outside the area between the two critical lines. The CUSUM test is based on the statistic;

$$W_t = \sum_{r=k+1}^{t} \frac{w_r}{s} \qquad (4.92)$$

Where t = k + 1..., T, w is the recursive residual and s is the standard error of the regression fitted to all T sample periods. Cumulative Sum of Square (CUSUMS) is based on the test statistic;

$$W_t = \frac{\left(\sum_{r=k+1}^{t} w_r^2\right)}{\left(\sum_{r=k+1}^{T} w_r^2\right)} \qquad (4.93)$$

The expected value of s under the hypothesis of parameter constancy is $E(s_t) = (t-k) \div (T-k)$ which goes from zero at t = k to unity at t = T. The significance of the departure of s from its expected value is assessed by reference to a pair of parallel straight lines around the expected value. The CUSUMS provides a plot of S_t against t and the pair of 5 percent critical lines. Movement outside the critical lines is suggestion of parameter or variance instability.

4.4.4 Granger Causality Test

Causality in the sense defined by Granger (1969) and Sims (1972) is inferred when lagged values of a variable, say X have explanatory power in a regression of a variable Y on lagged values of X and Y. The study of causality has widely been analysed using Vector Error Correction Model (VECM) and Error Correction Model (ECM). In these models, the variables are pre-tested for their unit root and cointegration properties and then a test of economic hypothesis expressed as restrictions on coefficients of the models is conducted. However, Toda and Yomamoto (1995) have shown that the asymptotic distribution of the test in the unrestricted VAR has nuisance parameters and nonstandard distributions. Also Toda and Yomamoto (1995), Zapata and Rambaldi (1997) and Rambaldi and Doran (1996) have all reported that approaches such as VECM and ECM used to analyse causality are sensitive to the values of the nuisance parameters in finite samples making the results a bit unreliable.

Toda and Yomamoto (1995) in reaction to the weakness associated with the standard granger causality test, proposed a modification of the Granger causality approach. This approach requires estimating a VAR model in their levels by augmenting the VAR model with the maximum order of integration, d, of the variables in the model. The method then applies the Wald statistic for linear restrictions to the resulting VAR (k) model. As shown by Toda and Yomamoto (1995), the Wald statistic for restrictions on the parameters of VAR (k) has an asymptotic χ^2 distribution when a VAR (k+dmax) is estimated (Zapata and Rimbaldi, 1997). Thus, the main idea is to intentionally over-fit the causality test underlying model with additional dmax lags so that the VAR order becomes (k+d) with k representing the optimal order of the VAR determined by AIC, SBC and HQC.

That is when one is uncertain about the order of integration of the variables, augmenting the VAR model with an extra lag usually ensures that the Wald statistic posses the necessary power properties. Thus, in applying the Toda and Yomamoto method all that is required of one is the maximum order of integration of the variables in the model and the optimal lag order of the VAR model. This method in contrast to the methods of Engle and Granger (1969) and Johansen and Juselius (1990) does not require pre-testing for cointegration and unit root properties and thus overcomes the pre-test biased associated with unit root and cointegration test. Also this method minimises the risk associated with possibly wrongly identifying the order of integration of the series and the presence of cointegration relationship (Giles, 1997; Mavrotas and Kelly, 2001).

Given the superiority of the Toda and Yomamoto causality approach over the standard Granger and VECM causality Approaches, this study adopts the Toda and Yomamoto causality test to test for the direction of causality between electricity consumption and economic growth in Ghana. The study, thus, estimate the following VAR model using the Seemingly Unrelated Regression (SUR) technique. As suggested by Rambaldi and Doran (1996) the Wald test experiences efficiency improvements when SUR models are used in the estimation.

$$EC_t = \alpha_0 + \sum_{i=1}^{k} \alpha_{1i} EC_{t-i} + \sum_{j=k+1}^{k+d_{\max}} \alpha_{2j} EC_{t-j} + \sum_{i=1}^{k} \beta_{1i} Y_{t-i} + \sum_{j=k+1}^{k+d_{\max}} \beta_{2j} Y_{t-j} + \varepsilon_{1t} \qquad \textbf{(4.94)}$$

$$Y_t = \gamma_0 + \sum_{i=1}^{k} \gamma_{1i} Y_{t-i} + \sum_{j=k+1}^{k+d_{\max}} \gamma_{2j} Y_{t-j} + \sum_{i=1}^{k} \lambda_{1i} EC_{t-i} + \sum_{j=k+1}^{k+d_{\max}} \gamma_{2j} EC_{t-j} + \varepsilon_{2t} \qquad \textbf{(4.95)}$$

Where k is the optimal lag length of the VAR, d_{max} is the maximum order of integration of the variables in the model. To investigate the causal relationship between electricity consumption and economic growth, the study tests two main hypotheses as described below.

4.4.4.1 Growth-Led-Electricity Hypothesis

To test for this hypothesis this study first estimate equation (4.94) and (4.95) using the Seemingly Unrelated Regression (SUR) technique. After the estimation of the equation, the study further test for the joint significance of the first K lagged values of per capita real GDP using the Wald statistic. Thus, the coefficients of the lagged values of the first k lags of per capita real GDP are restricted zero. In other words the study tests the following null hypothesis;

$$H_0 : \beta_{11} = \beta_{12} = ...\beta_{1k} = 0$$

As against the alternative hypothesis of

$$H_A : \beta_{11} = \beta_{12} = ...\beta_{1k} \neq 0$$

If the modified Wald test (MWT) test of significance finds the lagged values of the first k lags of per capita real GDP to be significantly different from zero, the null hypothesis will be rejected in favour of the alternative hypothesis. In this case we will say that economic growth drives electricity consumption. On the other hand if the MWT test of significance finds the lagged values of the first k lags of per capita real GDP to be not significantly different from zero, the null hypothesis is accepted. Thus, in this case we will say that economic growth does not drive electricity consumption.

4.4.4.2 Electricity-Led-Growth Hypothesis

To test for this hypothesis the study further carries on with the test of joint significance of the estimated coefficients of the first k lags of electricity consumption variable using Modified Wald Test (MWT). Thus, the study test the null hypothesis of

$$H_0 : \lambda_{11} = \lambda_{12} = ...\lambda_{1k} = 0$$

As against the alternative hypothesis of

$$H_A : \lambda_{11} = \lambda_{12} = ...\lambda_{1k} \neq 0$$

If the MWT test of significance finds the values of the first k lags of electricity consumption to be significantly different from zero, the null hypothesis will be rejected in favour of the alternative hypothesis. Thus, in this case we say that electricity consumption rather drives economic growth. However, if the MWT test of significance finds the values of the first k lags of electricity consumption not to be significantly different from zero, the null hypothesis will be accepted. In this case we say that electricity consumption does not drive economic growth.

In the event that both null hypotheses are rejected, it would mean that there exists a bidirectional relationship between electricity consumption and economic growth. However, in the case where both hypotheses are accepted, it would mean that there exist no causal relationship between electricity consumption and economic growth.

4.5 Conclusion

In this section the theoretical underpinning of the estimated model is provided. From the empirical specification in this study, electricity demand is assumed to be a function of real per capita GDP, industrial efficiency, structural changes in the economy, and degree of urbanisation. Also detail description of the estimation techniques adopted in the study is also provided. From the above discussion the superiority of the ARDL approach to cointegration over the Engle and Granger approach and Johansen multivariate approach to cointegration is established. This chapter also reveals the superiority of the Toda and Yomamoto Granger Causality test over the standard Granger causality test and the VECM Granger causality test. In the next chapter presentation and discussion of results are provided.

CHAPTER FIVE

PRESENTATION AND DISCUSSION OF RESULTS

5.0 Introduction

In this section details of estimated results are presented and discussed, providing likely reasons for the conclusions reached. Specifically in this section I conduct a test of unit root, appropriate lag length, deletion of deterministic variables, level relationship and parameter stability and test the electricity conservation hypothesis. Also long-run and short-run estimates and demand forecasts are provided. Microfit 4.0 and Eviews 4.1 are the statistical packages used for the estimation.

5.1 Unit root test for the included variables

Although it has been argued in the literature that the ARDL model does not require the pre-testing of variables for their order of integration, the approach requires that two pre-conditions are satisfied. The first of the conditions is that the dependent variable should be integrated of order one while the second condition requires that all variables in the ARDL framework be integrated of at most order one. To verify this I use the ADF test statistic and Phillip-Perron test to test for the presence of unit root in the variables in the model. Table 5.1 and table 5.1.1 present the results of ADF and Phillip-Perron tests of unit root of the included variables respectively. The null hypothesis is that there is a unit root.

Table 5.1: Augmented Dickey Fuller Test of unit root

Variables	ADF-Statistic	Decision	implication	Lag length
LNEC-levels	-1.767271	Do not reject null	Non stationary	2
D(LNEC)-first difference	-5.446603***	Fail to accept null	stationary	1
LNEF-levels	-2.907687**	Do not reject null	Non stationary	1
D(LNEF)-first difference	-5.780634***	Fail to accept null	stationary	1
LNY-levels	-0.555729	Do not reject null	Non stationary	1
D(LNY)-first difference	-4.128442***	Fail to accept null	Stationary	0
LNP-levels	-0.957999	Do not reject null	Non stationary	2
D(LNP)-first difference	-0.147039	Do not reject null	Non stationary	2
LNU-levels	-2.048439	Do not reject null	Non stationary	1
D(LNU)-first difference	-3.281351***	Fail to accept null	Stationary	0
LNV-levels	-1.154470	Do not reject null	Non stationary	2
D(LNV)-first difference	-4.879669***	Fail to accept null	stationary	1

*, **, *** indicate 1%, 10% and 5% level of significance. The lag length was chosen based on the Akaike Information Criterion.

Source: Author's computation

From table 5.1, the unit root test reveals that in levels all variables are non stationary except industrial efficiency (LNEF) which is stationary at the 10% level of significance. However, at their first difference the test reveals that all variables are stationary at the 5% level of significance except the population variable (LNP). For this reason the population variable is excluded from the model. This point is further justified using the alternative tests for non-nested regression models in later parts of this chapter.

Table 5.1.1: Phillip Perron test of unit root

Variables	PP-Statistic	Decision	implication
LNEC-levels	-2.072651	Do not reject null	Non stationary
D(LNEC)-first difference	-7.691418***	Fail to accept null	stationary
LNEF-levels	-2.2457	Do not reject null	Non stationary
D(LNEF)-first difference	-8.308901***	Fail to accept null	stationary
LNY-levels	-0.819665	Do not reject null	Non stationary
D(LNY)-first difference	-4.078915***	Fail to accept null	Stationary
LNP-levels	-0.834029	Do not reject null	Non stationary
D(LNP)-first difference	-1.986241	Do not reject null	Non stationary
LNU-levels	-1.65837	Do not reject null	Non stationary
D(LNU)-first difference	-3.270927***	Fail to accept null	Stationary
LNV-levels	-1.36708	Do not reject null	Non stationary
D(LNV)-first difference	-43.813619***	Fail to accept null	stationary

*, **, *** indicate 1%, 10% and 5% level of significance.

Source: Author's Computation

Since the ADF statistic has been criticised on the grounds that it has low power and size the study further used the Phillip Perron test, which is relatively better in terms of size and power. From table 5.1.1, the PP test of unit root confirms the test result by the ADF statistic. From table 5.1.1, all the variables in levels are non stationary. However, after taking the first difference of the series, the PP test statistic reveals that all the series are stationary except the population variable.

5.2 Bounds Cointegration test

The first step of the ARDL model is to test for the presence of long-run relationship (cointegration) between the dependent variable and the set of explanatory variables that explain it. Before conducting the Bounds cointegration test, this study first tests for the inclusion of a deterministic time trend in the ARDL model. The test of inclusion of a deterministic time trend tests the null hypothesis that the deterministic time trend is not statistically different from zero (see appendix 6). The resulting test statistics shows non rejection of the null hypothesis. Hence, in this study an ARDL model without a deterministic time trend is estimated.

Having determined the form of the ARDL model, I proceed to the test for cointegration in the variables. The test for the existence of level relationship (cointegration) in the ARDL model requires estimating equations (4.82a), (4.82b), (4.82c), (4.82d), and (4.82e) with OLS and testing for the joint significance of the lagged level variables. The computed F-statistic is then compared with the Pesaran and Pesaran asymptotic critical bounds for the F-statistic. Details of computed F-statistics are shown in appendixes 1 to 5. The critical values from the Pesaran et al have two critical bounds; lower critical bound and upper critical bound. Table 5.2 presents the result for the test of cointegration in the ARDL model based on the Bounds cointegration approach.

Table 5.2: Bounds Test for level relationship

F-statistic	**0.10**		**0.05**	
	Lower bound I(0)	**Upper bound I(1)**	**Lower bound I(0)**	**Upper bound I(1)**
F_{ec}(ec|ef,y,v,u) = 4.201 F_{ef}(ef|,ec,y,v,u) = 3.522 F_{y}(y|ef,ec,v,u) = 24.521 F_{v}(v|y,ef,ec,u) = 4.779 F_{u}(u|v,y,ef,ec) = 6.176	2.49	3.38	2.81	3.76

Source: Authors computation

From table 5.2, it is evident that for all the estimated equations except the industrial efficiency equation, the computed F-statistics exceed the 5% upper critical bounds. Hence, we fail to accept the null hypothesis of no level relationship. Thus, there exists cointegration or a long-run relationship between the dependent variables and the set of explanatory variables that explain them. For the electricity demand equation, the above result suggests that the variables lny, lnef, lnu, and lnv can be treated as the 'long-run forcing' variables for the explanation of lnec.

5.3 Log-linear Long-run Electricity Demand for Ghana

Since demand for electricity has electricity demand as the dependent variable, I estimate a long-run equation for electricity consumption. The estimated long-run coefficients are derived from the following ARDL estimates shown in table 5.2.1 below. It is important to point out that the long-run coefficients are associated with the level variables of the explanatory variables.

Table 5.2.1: Autoregressive Distributed Lag Estimates

ARDL (1,1,0,0,2) Selected based on Akaike Information Criteria Dependent Variable is LNEC 31 observations used for estimation from 1975 to 2005			
Regressor	Coefficient	Standard Error	T-Ratio [Prob]
LNEC (-1)	.47392	.13569	3.4928 [.002]
LNEF	-.57999	.037286	-15.5553 [.000]
LNEF (-1)	.37677	.097192	3.8766 [.001]
LNY	.83705	.43045	1.9446 [.065]
LNU	.32453	.10835	2.9951 [.007]
LNV	-.040187	.083011	-.48412 [.633]
LNV (-1)	.15623	.12581	1.2418 [.227]
LNV (-2)	.16965	.11360	1.4847 [.152]
CON	-1.6443	1.6830	-.97700 [.339]
R-Squared	0.98376	R-Bar-Squared	0.97785
S.E. of Regression	0.056906	F-stat F (8, 22)	166.5762 [.000]
Mean of Dependent Variable	8.3702	S.D. of Dependent Variable	.38239
Residual Sum of Squares	0.071243	Equation Log-likelihood	50.1855
Akaike Info. Criterion	41.1855	Schwartz Bayesian Criterion	34.7326
DW-statistic	1.8696	Dubin's h-statistic	.55406 [.580]

Source: Author's computation

The long-run parameter estimates as provided by Microfit are shown in table 5.2.2 below.

$$\ln EC_t = -3.126 - 0.386 \ln EF_t + 1.59 \ln Y_t + 0.617 \ln U_t + 0.541 \ln V_t - 0.006 \qquad (5.1)$$

Table 5.2.2: Log-linear long-run electricity demand for Ghana

Regressors	lnEF	lnY	lnU	lnV
Coefficients	- 0.386*** (0.0994)	1.591*** (0.5520)	0.617*** (0.1320)	0.541*** (0.1552)

*** indicates 5% level of significance. The maximum lag length was set to 2. The ARDL (1, 1, 0, 0, 2) was based on the AIC. The numbers in the parentheses represents the standard errors.
Source: Author's computation

From table 5.2.2, all the explanatory variables carried their expected signs. The industrial efficiency or efficiency improvement coefficient is found to be negative, inelastic and statistically significant. The estimated industrial efficiency coefficient indicates that for every 1% improvement in industrial efficiency that is achieved, a 0.386% of aggregate domestic electricity consumption is saved per annum in Ghana. Zauresh Atakhanova and Peter Howie (2007) also concluded that a 1% improvement in industrial efficiency will reduce electricity consumption by 0.33% for Kazakhstan. This implies that as firms adopt more efficient forms of technology in their production activities, the industrial electricity intensity declines. Thus, more output is being produced with less electricity. Not only does this helps to conserve electricity in the country but also acts as a cost saving measure for industries, hence increase in industrial profit. The result obtained with regard to industrial efficiency in this study also confirms the results obtained by Lin (2003) and Issa and Bataineh (2010) who in their study also find industrial efficiency elasticity to be -0.187 and -0.04 for China and Kahzarkstan respectively. The XPlot of electricity consumption and industrial efficiency as shown in figure 5 below confirms the negative inelastic nature of electricity consumption to industrial efficiency improvements.

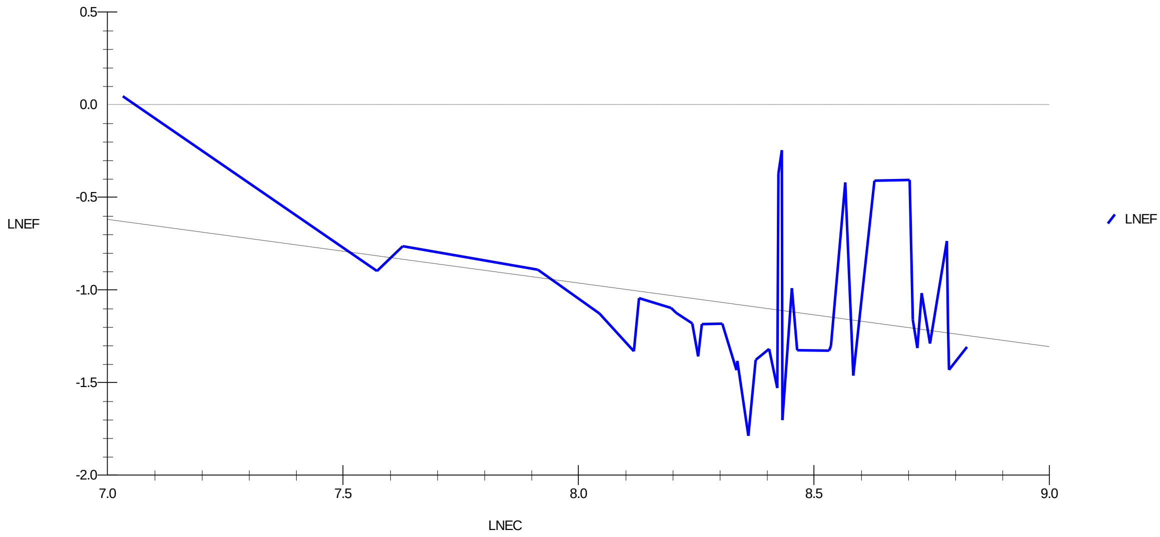

Figure 5: XPLOT of Electricity consumption and Industrial efficiency
Source: Author's computation

The estimated long-run income elasticity is found to be positive, elastic and statistically significant. This means that electricity is a normal good. Thus, a 1% increase in real per capita GDP will result in a 1.59% increase in aggregate domestic electricity demand in Ghana. Thus, a proportionate growth in the economy will lead to a more than proportionate growth in electricity demand in Ghana. The relatively high value confirms that with further economic development of the country, one can expect to see a rise in the aggregate domestic consumption of electricity. The positive elastic nature of electricity consumption to real per capita income is confirmed in the XPLOT shown in figure 5.1 below.

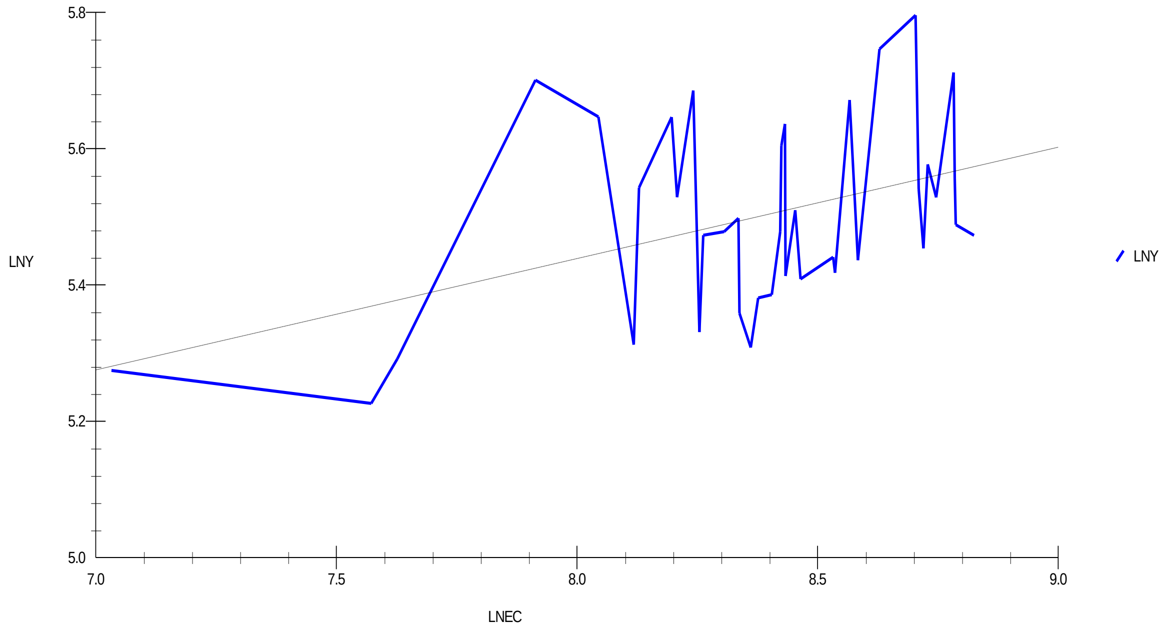

Figure 5.1: XPLOT of Electricity consumption and Real Per Capita GDP
Source: Author's computation

The transmission mechanism of this could be explained as follows. Since real per capita GDP is a measure of economic performance, increase in real per capita GDP creates avenue for increased investments to be made in the economy. These capital investments positively drive electricity consumption since most of these capital investments are technological in nature which are highly energy driven.

Also increased real per capita GDP implies increase in household incomes. As household incomes increase their purchase of electricity-consuming appliances increase which increase their usage of electricity. The result of this study confirms result of a number of studies such as Houthakker et al (1973), Rahman (1982), Ang (1988), Amusa et al (2009) and Huang (1993) who all found income elasticity of electricity demand to be greater than unity in the long-run.

The estimated degree of urbanisation coefficient is found to be positive, less inelastic and statistically significant. The estimated coefficient implies that a 1% increase in urban population growth will result in a 0.617% increase in aggregate domestic electricity demand in Ghana. In other words, there exist a positive disproportionate relationship between degree of urbanisation and electricity demand. The positive urbanisation coefficient is explained by the fact that urbanisation implies greater access to electricity, since households can easily be connected to the grid. Also consumers who already had access to electricity before moving are most likely to increase their consumption once they find themselves in urban setting. The higher energy intensity of urbanites even if decreasing with time will mean continued urbanisation will increase electricity demand throughout the country. Holtedahl and Joutz (2004) also found a similar result for Taiwan. The XPLOT of electricity consumption and degree of urbanisation shown in figure in 5.2 below confirms the positive inelastic nature of electricity consumption to degree of urbanisation.

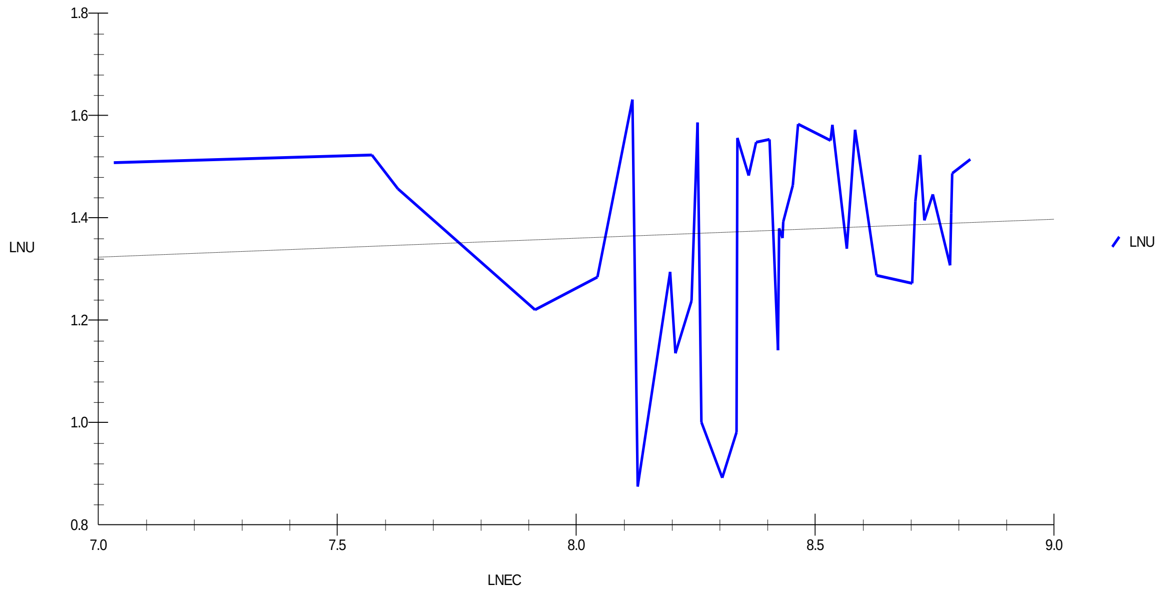

Figure 5.2: XPLOT of electricity consumption and degree of urbanisation.
Source: Author's computation

Lastly, the coefficient for structural changes in the economy is found to be positive, less inelastic and statistically significant at the 5% level of significance. The estimated coefficient implies that a 1% increase in industrial share of GDP will result in a 0.514% increase in aggregate domestic electricity demand. The lower output elasticity is explained by the fact that, in periods of rapid economic expansion, increments in output could be associated with non-electricity intensity process or the full potential of modern efficient capital equipment would not be realised at the higher levels of output. This conclusion is in line with Zuresh and Peter (2007) who found structural changes in the economy to have a significant positive impact on electricity consumption in Kazakhstan. Specifically they found that a 1% increase in industries' share of GDP would increase electricity consumption in Kazakhstan by 0.28%. With the extraction of oil in commercial quantities in Ghana, which purports to bring on board influx of energy intensive industries, the result imply that growth in electricity consumption will continue into the future. The XPLOT herein confirms the positive less inelastic nature of electricity consumption to structural changes in the economy as shown in figure 5.3.

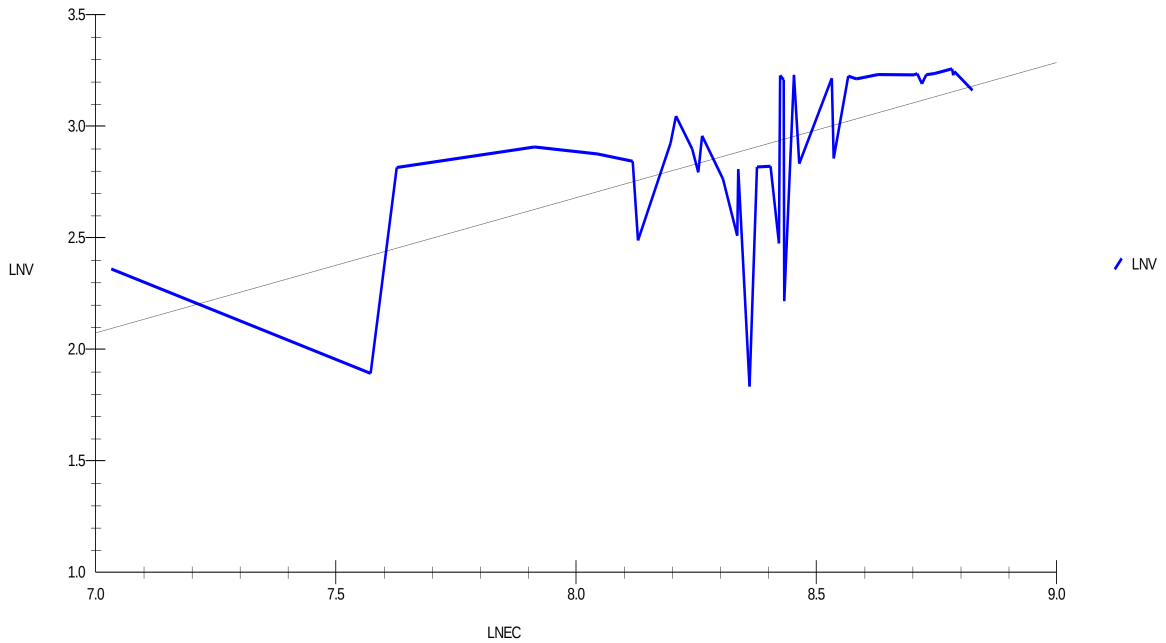

Figure 5.3: XPLOT of Electricity consumption and Structural changes in the economy
Source: Author's computation

Thus, in the long-run, income effects play the primary role while efficiency effects, output effects, and demographic effects play the secondary role in explaining the historical patterns of domestic electricity demand in Ghana. The result obtained in this study indicates that efficiency improvement is the only factor that drives domestic consumption of electricity downwards. However, the negative efficiency effects have been insufficient to outweigh the positive income effects, output effects, and demographic effects, hence the continual increase in domestic consumption of electricity in Ghana.

5.4 A Log-linear Error Correction Model for Ghana

The last stage of the ARDL model involves estimating an error correction model. The result of the estimated coefficients of the error correction model is presented in table 5.2.3 below;

Table 5.2.3: Log-linear short-run estimates of electricity demand in Ghana

Regressor	dlnEF	dlnY	dlnU	dlnV	dlnV1	ECT
Coefficient	-0.580*** (0.0373)	0.837** (0.4305)	0.325*** (0.1084)	-0.040 (0.0830)	-0.169 (0.1136)	-0.526*** (0.1357)
R-Squared	0.96445		R-Bar-Squared	0.95152		
S.E. of Regression	0.056906		F-stat	f(6, 24)	99.4744(0.000)	
Residual sum of squares	0.071243		equation log-likelihood	50.1855		
Akaike Info. Criterion	41.1855		Schwartz Bayesian Criterion	34.7326		
DW-Statistic	1.8696					

ARDL (1, 1, 0, 0, 2) was chosen based on AIC. **, *** indicates 10% and 5% level of significance. The numbers in the parentheses represents standard errors.
Source: Author's computation

From table 5.2.3, the short-run income elasticity coefficient is positive, inelastic, significant at the 10% level of significance and lower than the long-run income elasticity coefficient. This confirms what has been established in the literature that in the long-run income elasticity tends to be more elastic than in the short-run. The short-run income effects imply that a 1% increase in income will lead to a 0.84%

increase in electricity demand. In other words the positive income effects on electricity demand shrink in the short-run. This result confirms Lin (2003) and Holtedahl and Joutz (2004) who all found the income elasticity coefficient in the short-run to be inelastic and lower than the long-run income elasticity.

The degree of urbanisation coefficient is found to be positive and inelastic and significant at the 5% level of significance. Compared to the long-run estimate, the short-run urbanisation elasticity coefficient is more inelastic indicating that the impact of growth of the urban population on electricity demand diminishes in the short-run. This could possibly be explained as follows. In the short-run, the time is too short for adjustments to be made in electricity consuming appliances of households; hence, growth in the urban population comes with a relatively small change in domestic electricity consumption, hence the low urbanisation elasticity. However, in the long-run, there is the possibility of adjustments to be made in electricity consuming appliances of households; hence, growth in the urban population comes with a relatively large change in domestic electricity consumption, hence the relatively high elasticity in the long-run (though less than one).

Another variable worth discussing is the industrial efficiency variable. The estimated coefficient retained the expected sign and is significant at the 5% level of significance. The short run efficiency elasticity indicates that for every 1% improvement we achieve in industrial efficiency, a total of 0.58% of electricity consumption would be saved per annum. However, compared to the long-run estimate, the short-run elasticity is less inelastic. Thus, for every 1% improvement in industrial efficiency achieved, a 0.58% and 0.386% of electricity consumption is saved per annum in the short-run and long-run respectively. This could be explained by the fact that most acquired technological equipments investments by firms are short-term oriented. As a result their efficiency level in terms of electricity consumption improves. However, in the long-run, investments by firms are mostly replacement investments. As a result the electricity efficiency of capital equipments in the long-run reduces. Thus, newer capital equipments are more electricity efficient than old capital equipments ceteris paribus. This result is in line with Lin (2003)[22] who also found the industrial efficiency elasticity to be less inelastic in the short-run than in the long-run.

Structural change in the economy is, however, found to have no explanatory power in the short-run. Of outmost is the error correction term coefficient. The coefficient of the error correction term carried the expected sign which is highly significant and very large as well. This suggests that in Ghana when there is a shock in the electricity sector convergence to equilibrium is relatively high with 52.6% of adjustment occurring in the first year. In other words, for an initial error of 1%, 52.6% of this error would be corrected in the first year.

The result presented above indicate that in the short-run, industrial efficiency, real per capita GDP, and degree of urbanisation are the most important factors that coerce aggregate domestic electricity consumption in Ghana.

5.5 Diagnostic Test

The diagnostic tests conducted in this study include the test for serial correlation, normality, heteroscedasticity, parameter stability, and functional form specification. The result of these tests is as shown in table 5.2.4 below.

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[22] Lin (2003) estimated the long-run industrial efficiency elasticity coefficient to be -0.187 and the short-run elasticity coefficient to be -0.8319.

Table 5.2.4: DIAGNOSTIC TESTS

Test Statistic	LM Version	F-Version
A: Serial Correlation	CHSQ (1) = .00531[.942]	F (1, 21) = .0035964[.953]
B: Functional Form	CHSQ (1) = .95494[.328]	F (1, 21) = .66745[.423]
C: Normality	CHSQ (2) = .16586[.920]	Not applicable
D: Heteroscedasticity	CHSQ (1) = .36660[.545]	F (1, 29) = .34705[.560]

A: Lagrange multiplier test of residual serial correlation

B: Ramsey's RESET test using the square of the fitted values

C: Based on a test of skewness and kurtosis of residuals

D: Based on the regression of squared residuals on squared fitted values

Source: Author's Computation

The test for serial correlation tests the null hypothesis that the residuals are not serially correlated. From the test statistic shown in table 5.2.4, we fail to reject the null hypothesis. Thus, the residuals of the estimated model are not serially correlated. The test of functional form tests the null hypothesis that the functional form of the model is not mis-specified. From the LM and F-statistic we fail to reject the null hypothesis. Thus, the estimated model is correctly specified. The test for normality tests the null hypothesis that the residuals of the model are normally distributed. The test statistic displayed in table 5.2.4 above indicates non rejection of the null hypothesis. Thus, the residuals of the model are normally distributed. The histogram plot of the residuals of the model as shown in figure 5.4 below also confirms this conclusion.

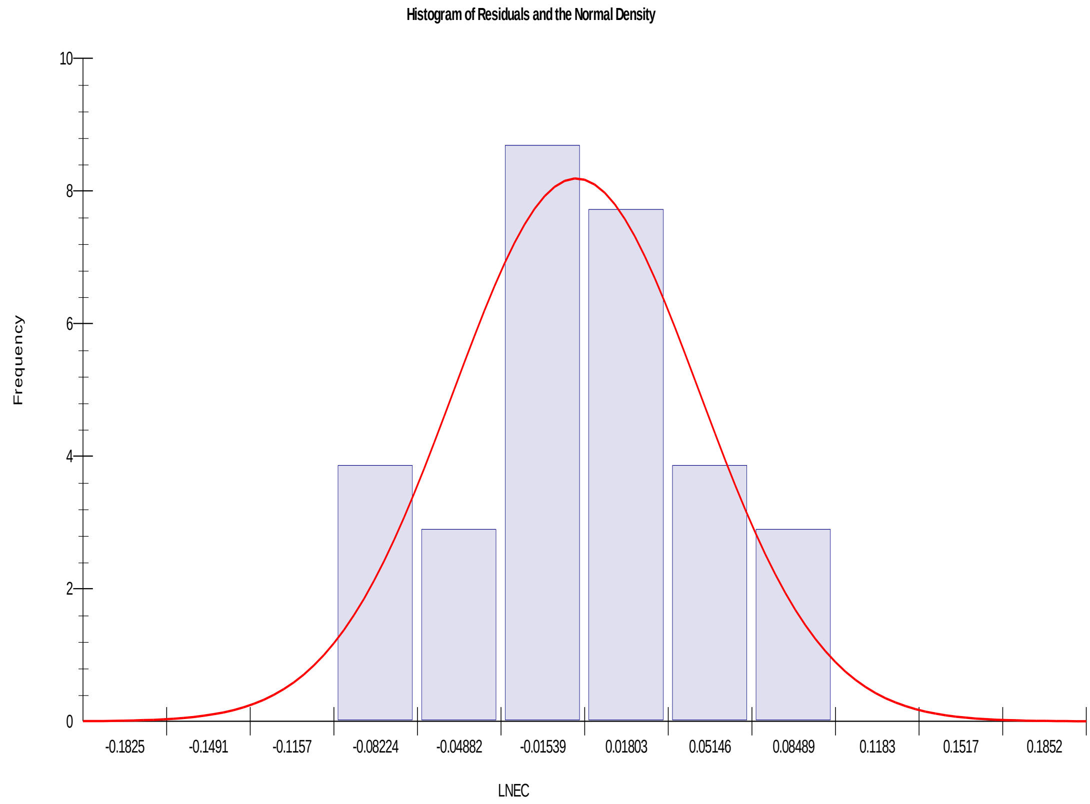

Figure 5.4: Histogram of Residuals and the Normal density
Source: Author's computation

Finally, the study tests to see whether the variances of the residuals are constant or varying. The test for heteroscedasticity tests the null hypothesis that the residuals of the model are homoscedastic. The test result as shown in table 5.2.4 above indicates non rejection of the null hypothesis. Given R-squared value of 0.98376, the estimated regression reasonably fits well.

The possible existence of structural breaks in series has the potential effect of rendering model parameters varying with time.To test whether the estimated coefficients are stable over the sample period, the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMS) of the recursive estimation of the conditional error correction model is provided. The plots of CUSUM and CUSUMS are as shown in figures 5.5 and 5.6 respectively.

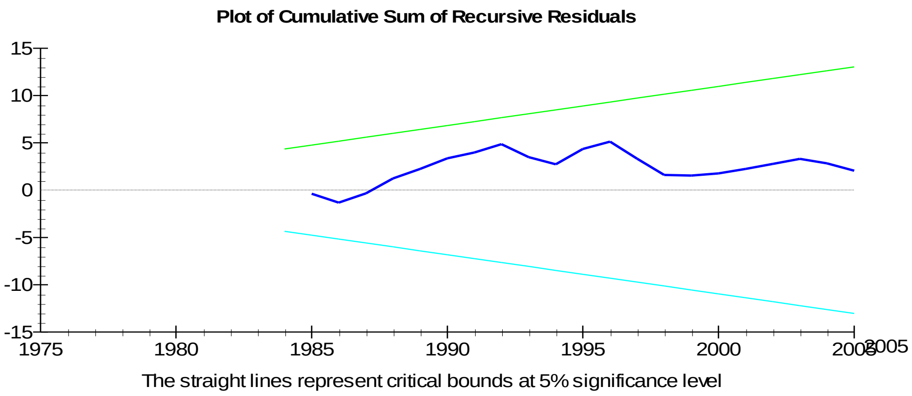

Figure 5.5: Plot of Cumulative Sum of Recursive Residuals
Source: Author's computation

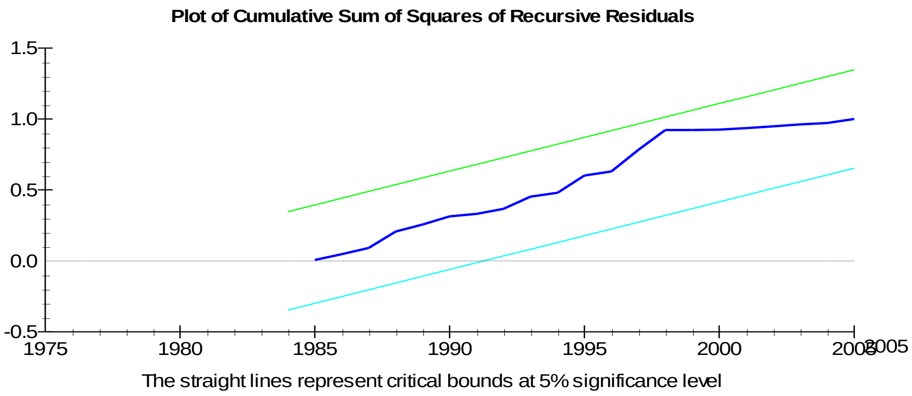

Figure 5.6: Plot of Cumulative Sum of Squares of Recursive Residuals
Source: Author's computation

The two straight lines represent critical bounds at 5% significance level. As depicted in figures 5.5 and 5.6, the estimated CUSUM and CUSUMS fall within the 5% critical bounds. Thus, the test of parameter stability reveals that the estimated coefficients are stable over the entire sample period. Thus, in all, the result of the conducted diagnostic tests show that the estimated regression fits reasonably well and passes the diagnostic tests against non-normal errors, functional form misspecification, parameter instability, heteroscedasticity and serial correlation test.

However, it is important to say here that, the fact that the model passes all the diagnostic tests does not make such a model a good one. As a result the study proceeds to test for non-nested alternative regression models. In this test, two models are compared for their adequacy and efficiency. In this study the alternative model is the population augmented model (M2). Thus, the original estimated model (M1) is augmented with the population variable. Below is the test result for the non-nested alternative regression models.

Table 5.2.5: Non-nested statistics for testing ARDL

Test statistic	**N-Test**	**NT-Test**	**W-Test**	**J-Test**	**JA-Test**	**encompassing**
M1 against M2	-2.1075 (0.035)	-1.6320 (0.103)	-1.4712 (0.141)	1.4483 (0.148)	1.4483 (0.148)	2.0975 (0.162)
M2 against M1	-7.9529 (0.000)	-4.7551 (0.000)	3.3379 (0.001)	4.6150 (0.000)	3.2430 (0.001)	4.7767 (0.007)
AIC of M1 versus M2 = 5.5533 favours M1 SBC of M1 versus M2 = 3.4023 favours M1						

Figures in the parenthesis represent p-values
Source: Author's computation

From table 5.2.5, it is evident that all the alternative test of non-nested regression models favour model 1, although the N-Test provides a contradictory result. The AIC and SBC of model 1 versus model 2 both favour model 1. The result presented here further complements the adequacy and efficiency of the estimated model.

5.6 Granger Causality Test

One of the main objectives of this paper is to test the electricity conservation hypothesis. This is done by investigating the direction of causality between electricity consumption and economic growth in Ghana. The Toda and Yomamoto approach to granger causality test is used. The Toda and Yomamoto approach requires the optimal order of the VAR and the highest order of integration of the variables. As a result, the study first conducts a test of optimal lag length of the VAR. This test is based on the Akaike Information Criterion. Detail of this test is shown in appendix 16. The result of the test based on Akaike Information criterion (AIC)[23] selects the optimal lag length order of two (2).

The next step requires testing for the inclusion or exclusion of deterministic variables in the VAR. The LR test of deletion of deterministic variables in the VAR which follows the chi-square distribution is used. Result of the test suggests the inclusion of an intercept and a deterministic time trend in the VAR. Detail of this test is shown in appendix 17.

5.6.1 LR test of Block Granger Non-causality in the VAR

The study first adopts the Log-likelihood Ratio test of Block Granger Non-causality in the VAR to investigate the electricity-economic growth nexus. The LR test of block granger non-causality statistic tests the null hypothesis that the coefficients of the lagged values of the variable assumed to be "non-causal" in the block of equations explaining other variables are zero. The test is based on a chi-square distribution. Result of the test is shown in table 5.2.6 below.

[23]When AIC and SBC estimates are based on ordinary least square, the test chooses the criterion with the minimum figure. However, when AIC and SBC estimates are based on log-likelihood, the test chooses the criterion with the maximum value. In Microfit, estimates of AIC and SBC are based on log-likelihood hence the model with the highest value is chosen.

Table 5.2.6: LR test of Block Non-causality in the VAR

Null hypothesis	LR statistic	Decision
Electricity consumption does not cause real per capita GDP	2.5074 (0.285)	Do not reject null
Real per capita GDP does not cause electricity consumption	9.0107^{***} (0.011)	Fail to accept null

*** indicates 5% level of significance. The maximum lag length is 2. Figures in the parenthesis represent p-values.

Source: Author's computation

From the test statistic, I fail to reject the null hypothesis that electricity consumption does not granger cause real per capita GDP. However, I fail to accept the null hypothesis that real per capita GDP does not granger cause electricity consumption at the 5% level of significance. Thus, from the result of the LR test of block granger non-causality, there exist a unidirectional causality running from real per capita GDP to electricity consumption in Ghana. Hence electricity conservation is a viable option for Ghana.

5.6.2 Toda and Yomamoto Granger Causality Test

Following from the result of the test of lag length choice order, deletion of a deterministic variable in the VAR and unit root test, I estimate equations (4.94) and (4.95) using Seemingly Unrelated Regression where K is 2 and d_{max} is 1 and restricts the coefficients of the variables assumed to be non causal to zero. Table 5.2.7, shows the resulting Wald test statistic (see appendix 12 and 14).

Table 5.2.7: Toda and Yomamoto Granger causality test

Null hypothesis	Wald statistic	Decision
Electricity consumption does not cause real per capita GDP	0.72479 (0.696)	Do not reject null
Real per capita GDP does not cause electricity consumption	10.8149^{***} (0.004)	Fail to accept null

*** indicates 5% level of significance.

Source: Author's computation

As shown in table 5.2.7 above, the Wald test statistic[24] reveals non rejection of the null hypothesis that electricity consumption does not granger cause real per capita GDP. However, the Wald test statistic reveals non acceptance of the null hypothesis that real per capita GDP does not granger cause electricity consumption in favour of the alternative hypothesis that real per capita GDP granger causes electricity consumption. Thus, the Toda and Yomamoto granger causality test also provide evidence of unidirectional causality which runs from real per capita GDP to electricity consumption which confirms the conclusion reached based on the LR test of Block non-causality in the VAR. Thus, data on Ghana supports the Growth-led-Energy consumption hypothesis hence rejection of the null hypothesis that electricity conservation is not a viable option for Ghana. This result supports the works by Wolde-Rufael (2006) and Twerefo et al (2008) but contradicts Akinlo (2008) and Lee (2005).

5.7 Evaluation of the forecasting ability of the estimated model

The essence of correctly identifying the effects of factors that affect electricity demand is to primarily obtain a precise or accurate forecast for electricity demand. Developing accurate demand forecasts is therefore an important instrument in the success of recent energy reforms. However, as argued in chapter two, official electricity demand forecasts in the country have largely deviated from the actual. It is against this background that, as an objective of this work, an econometric forecast of electricity demand based on the Autoregressive Distributed Lag model is proposed.

The dynamic forecast for the change in electricity consumption is based on the above estimated error correction model. The dynamic forecast allow for both short-

[24] Details of the SURE model and test of restriction based on the Wald test are shown in appendixes 18 to 21.

run and long-run changes. Specifically the study provides forecasts for the periods 2006 to 2008, which is a three year period. These periods are used to evaluate the forecasting ability of the estimated model. Table 5.2.8 below presents the result of demand forecast based on the ARDL model from 2006 to 2008.

Table 5.2.8: Dynamic conditional forecast for the change in electricity demand

Observation	**Actual demand (GWh)**	**Prediction (GWh)**
2006	6,519 (22%)	6,654 (24%)
2007	5,589 (-15%)	5,645 (-16%)
2008	6,024 (7.5%)	6,119 (8%)
Summary statistics for residuals and forecast errors		
Estimation Period (1975-2005)		**Forecast Period (2006-2008)**
Mean= -0.0000		Mean = -0.00152319
Mean Absolute= 0.036899		Mean Absolute = 0.012128
Mean Sum Squares= 0.0022981		Mean Sum Squares = 0.001862
Root Mean Sum Squares= 0.047939		Root Mean Sum Squares = 0.013646

Figures in the parenthesis represent the annual percentage changes. The ARDL (1, 1, 0, 0, 2) model was chosen based on AIC

Source: Author's computation

From Table 5.2.8, the root mean squares of forecast errors of 1.4 percent per annum compares auspiciously with the value of the same criterion computed over the estimation period. Also the plot of in-sample fitted values and out of sample forecasts show that the forecasted values and the actual are like two peas in a pod. Thus, the model better explains the pattern of movements in domestic electricity consumption. This is evident in figure 5.7 below.

Figure 5.7: Plot of in-sample fitted values and out of sample forecasts

Source: Author's computation

To add to the above forecast evaluation criteria, I further compute the Mean Absolute Percent Error (MAPE)[25] and the Theil Inequality Coefficient (TIC)[26] of the forecast since these statistics are not provided in Microfit. The estimated values of the MAPE and TIC of the forecast of 7.8 percent and 0.003 respectively further confirm the suitability of the forecast model.

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[25] $MAPE = \frac{100}{N}\sum_{t=1}^{N}\left|\frac{A_t - P_t}{A_t}\right|$

[26] $TIC = \frac{\sqrt{\frac{1}{T}\sum_{t=1}^{T}(A_t - P_t)^2}}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}P_t^2} + \sqrt{\frac{1}{T}\sum_{t=1}^{T}A_t^2}}$, where A is the actual, t is the time period, and P is the predicted

5.7.1 Dynamic Conditional Forecast for Aggregate Electricity Demand from 2009 to 2019

I proceed to obtain conditional forecasts for electricity consumption from 2009 to 2019 and compare with the national forecasts provided by VRA and GRIDCo. The conditional forecasts provided in this work is based on national projections of real GDP per capita, World population prospects for degree of urbanisation and ARIMA based forecast for industries' share of GDP and industrial efficiency.

The ARIMA models are tested against the existence of serial correlation in the residuals. The Breusch-Godfrey serial correlation LM test concludes that the estimated ARIMA models do not suffer from any serial correlation problem. Also the study tests for the existence of structural breaks in industry share of GDP and industrial efficiency using the Chow forecast test. The result of the test reveals non rejection of the null hypothesis that prediction errors of the forecasted observation are zero in industry share of GDP and industrial efficiency. The plot of the actual and fitted values of industry share of GDP and industrial efficiency also indicates that the estimated ARIMA models really explains the pattern of movements in industry share of GDP and industrial efficiency. Details of the ARIMA based forecasting are shown in appendixes 7 to 13. The dynamic conditional forecasts in this study is based on the following assumptions;

- Real per capita GDP is projected to grow at 8% per annum (source: Ghana's Vision 2020)
- Degree of urbanisation is projected to grow at 3.11% from 2009 to 2015 and 2.8% from 2015 to 2020 (source: 2005 World Population Prospects)

The result of the dynamic conditional forecasts[27] compared with the national load forecast by GRIDCo and VRA is as shown in table 5.2.9 below.

Table 5.2.9: Conditional Domestic Load Forecast (in GWh) from 2009 to 2019

Year	**Conditional Load forecast**	**GRIDCo forecast**	**VRA forecast**
2009	7324	NA	NA
2010	7994	8932	8758
2011	8,892	9,592	9,476
2012	9,973	10,674	10,137
2013	11,090	11,977	11,835
2014	12,372	13,950	12,377
2015	13,947	15,703	12,943
2016	15,722	17,166	13,538
2017	17,578	17,618	14,350
2018	19,596	18,086	15,052
2019	21,974	18,682	15,864

Source: Author's computation, GRIDCo, and VRA

From Table 5.2.9, domestic load demand is projected to increase from 7,324 GWh in 2009 to 21,974 GWh in 2019 which represents an annual average growth rate of 11.8%. Compared to GRIDCo and VRA's domestic load demand forecast, the conditional forecasts obtained in this study represents an increase in the annual average growth rate of domestic load of 3.8% and 6.8% respectively. Much of this growth is expected to be driven significantly by industrial and residential consumption. Figure 5.8 below plots the evolution of the national domestic demand forecast from 2009 to 2019.

[27] See appendixes 14 and 15 for details of the dynamic conditional forecast for change in electricity consumption

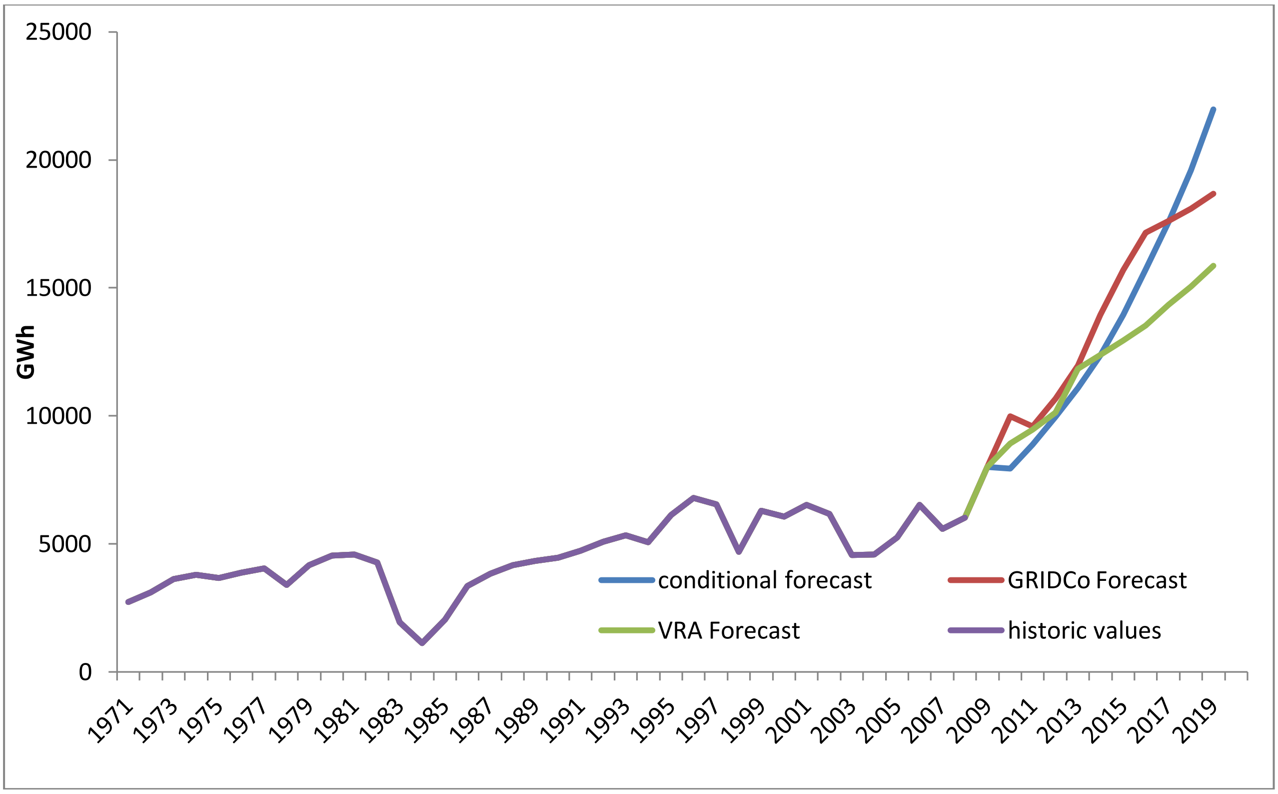

Figure 5.8: Evolution of national domestic demand forecast
Source: Author's Compilation

Comparing our obtained forecasts with the national domestic load forecasts provided by GRIDCo, domestic electricity consumption is predicted much relatively high by GRIDCo for most of the years except for the years 2018 and 2019. Similarly, the domestic load forecasts by VRA predict domestic electricity consumption much higher for the first five years relative to the conditional forecast. However, the conditional forecasts predict a much comparatively high domestic load for the last five years of the forecasting period. Given the varying forecasting models and assumptions upon which these forecasts are based, the variability in the forecast values of domestic load is highly anticipated.

Based on VRA's forecast of total plant capacity increase, the required plant capacity increase based on the conditional load forecasts in this study is predicted to be 1,419 MW. Using the 2010 total installed capacity of 2,346 MW as the base period; the forecast of the required total plant capacity increase represents an increase of about 60 percent. Judging by the current national supply plan for electricity which has the Bui dam (which is expected to add 400 MW) as the only hydro project, the result obtained implies that the remaining 1,019 MW is expected to be thermal based. Thus, the conditional forecast implies that thermal generation as a percentage of the total installed capacity is expected to increase from the current 40% to 58% by 2019. Given the fact that thermal generation is highly capital intensive and energy intensive, the above result suggests a possible increase in the future cost of producing electricity in the country hence a rise in future electricity prices all things being equal. The lack of consensus between government and utility companies on tariff rates due to differing interest always poses the challenge of adjusting tariffs to reflect the true marginal cost of producing electric power. However, the persistence of unremitting low electricity tariff rates into the future would mean increased cost of recurrent power outages in the country.

5.8 Summary of Findings vis-a-vis the Study Objectives

This thesis set up for itself three core objectives. These include;

- Estimate future electricity demand and identify the factors that underlie the historical growth trends in aggregate domestic electricity demand both in the short and long-run periods.
- Determine whether electricity conservation is a viable option for Ghana
- Determine the future required plant capacity increase.

From the estimated aggregate domestic electricity demand equation, real per capita GDP, industrial efficiency, structural changes in the economy, and degree of urbanisation ard identified as the factors that significantly explains the long-run growth in aggregate domestic electricity demand in Ghana. However, in the short-run, real per capita GDP, industrial efficiency, and degree of urbanisation are found to be the core factors that explain growth in aggregate domestic electricity demand. Industrial efficiency is the only factor found to have a negative effect on aggregate domestic electricity demand, however, the negative efficiency effect is less relative to the positive income, demographic, and output effects, hence the continual growth in aggregate domestic electricity consumption in Ghana.

The causality test based on the Toda and Yomamoto Granger Causality reveals that there exists a unidirectional causality running from real per capita GDP to electricity consumption. Thus, data on Ghana supports the Growth-led-Energy Hypothesis; hence electricity conservation is a viable option for Ghana.

The dynamic conditional forecast projects aggregate domestic electricity demand to increase from 7,324 GWh in 2009 to 21,974 GWh in 2019 which represents an annual average growth rate of 11.8 percent. Based on the projected growth in electricity consumption, the total required plant capacity increase is projected to be 1,419 MW which represents an increase of 60% above the 2010 figure. This further implies that thermal generation as a percentage of total installed capacity is predicted to increase from the current 40% to 58% by 2019.

Comparing the findings in this thesis with the above stated objectives, this clearly indicates the attainment of the stated objectives that this thesis set to achieve.

5.9 Conclusion

In all, the study identified real per capita GDP, industrial efficiency, structural changes in the economy and degree of urbanisation as the major determinants of domestic consumption of electricity in the long-run. Our result obtained in relation to structural changes in the economy implies that growth in electricity demand is expected to continue into the future with the emergence of new market, the oil market. However, in the short-run, industrial efficiency, real per capita GDP and degree of urbanisation were found to be the main drivers of domestic electricity consumption. Also demand forecast based on the ARDL framework suggests that the official demand forecast by GRIDCo and VRA predicts a relatively high growth of domestic load for most of the years and the first five years of the forecasting period respectively. Also evidence of unidirectional causality running from economic growth to electricity consumption was found.

CHAPTER SIX

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.0 Introduction

In this part of the study, I present the major conclusions reached from the study. Based on these conclusions, recommendations are made for policy makers and future researchers.

6.1 Summary

In spite of the policy relevance associated with identifying and quantifying the effects of factors that affect electricity demand, there is still a dearth of research studying the problem in developing countries and Ghana for that matter. This thesis therefore, estimates future electricity demand, identifying the main determinants of demand for electricity and quantifying their specific effects and testing the electricity conservation hypothesis. Specifically the study uses the sample 1975 to 2008. The estimated demand equation is based on an ARDL framework while the Toda and Yomamoto Granger causality test is used to test for the direction of causality between electricity consumption and economic growth.

An overview of the power sector in Ghana reveals a situation of increasing power shortage in the electricity sector and declining trend in net import of electricity. Also it was established that power outages in Ghana could cost consumers US$ 974 million every year which represents 6% of GDP compared to World Bank estimates of 2%.

The regression result of the determinants of electricity demand in Ghana reveals that in the long-run, real per capita GDP, industrial efficiency, structural changes in the economy, and degree of urbanisation play significant role in explaining electricity demand. However, in the short-run real per capita GDP, industrial efficiency, and degree of urbanisation play significant role in explaining electricity demand in Ghana.

Based on the forecast obtained in this study, the official forecasts by GRIDCo predict a relatively high growth for domestic load while VRA domestic load forecast predict a relatively high growth for domestic load for the first five years of the forecasting period and a much lower growth for the last five years of the forecasting period.

The test of the direction of causality between electricity consumption and economic growth reveals that in Ghana there exists a unidirectional causality running from energy consumption to economic growth.

6.2 Conclusions

In the test of the long-run relationship where each variable was normalised as a dependent variable, the study finds evidence of the existence of level relationship between the set of dependent variables and the corresponding explanatory variables at the 5% significance level except for the industrial efficiency equation which was significant at the 10% significance level. Specifically, the study finds the existence of cointegration between the dependent variable, electricity demand, and the set of explanatory variables that explains it. This implies that real per capita GDP, industrial efficiency, degree of urbanisation, and structural changes in the economy can be treated as the 'long-run forcing variables' that explains changes in aggregate domestic electricity demand.

Using the ARDL model, the study finds real per capita GDP, structural changes in the economy and degree of urbanisation to have a significant positive impact on aggregate domestic consumption of electricity except industrial efficiency which has a negative effect on aggregate domestic electricity consumption in the long-run. However, in the short-run electricity demand is significantly explained by real per capita GDP, industrial efficiency, and degree of urbanisation..

The error correction term, which is a measure of disequilibrium error, was found to be negative, large and significant. This means that short-run shocks or disturbances in the electricity sector will quickly move the economy towards her long-run equilibrium. Compared with the economies of China, South Africa, and Tawain Ghana's convergence to long-run equilibrium rate for every initial shock in the electricity sector is higher. A test of parameter stability based on CUSUM and CUSUMS plots also reveals constancy of the estimated parameters of the model.

Empirical investigations into the energy-economic growth nexus have important policy implications. However, as stated in the literature, results from studies on the energy-economic growth nexus have been mixed. The case is not different for Ghana. To add to the prevailing arguments in the literature this study further investigates the causal relationship between electricity consumption and real per capita GDP using Toda and Yomamoto Granger causality test. The study finds evidence of unidirectional causality running from real per capita GDP to electricity consumption. Thus, data on Ghana supports the Growth-Led-Energy Hypothesis. Given that Ghana's economy is highly driven by the agricultural (subsistence in nature) and service sectors, which are less mechanised, the implication of this conclusion is that electricity conservation measures will not have the potential effect of swaying the economy from her macroeconomic targets.

Based on the error correction model, a dynamic forecast for domestic electricity demand was obtained. Specifically domestic electricity consumption is predicted to increase from 7,324 GWh in 2009 to 21,974 GWh in 2019. Compared with GRIDCo's load forecasts, GRIDCo predicts a much higher growth of domestic load for most part of the forecasting period. Also comparing with load forecasts by VRA, VRA predicts a relatively high growth in domestic load for the first five years of the forecasting period and a relatively low growth of domestic load for the last five years of the forecasting period. This result implies that thermal generation as a percentage of total installed capacity is expected to increase from the current 40% to 58% by 2019 giving the current national supply plans for power generation. Thus, future cost of production of electricity, hence electricity tariffs, is expected to rise.

6.3 Recommendations

Based on the results of this study, the following recommendations are made.

First, Mandatory industrial equipment minimum electricity performance standards should be adopted. This has the budding of escalating market diffusion of more efficient equipments and providing standardised electricity efficiency progress in the industrial sector.

Funds should be billed to carry out studies that document the full cost and benefits of adopting electricity efficiency technologies, practices, and measures. Also an evaluation of potential and description of existing industrial electricity efficiency policies should be carried. These will help the development of national electricity efficiency plan which set ambitious and achievable national electricity efficiency goals or targets for the industrial sector.

Proprietary electricity efficiency technologies and processes that have significant electricity-savings potential should be identified systematically. Also options should be provided to facilitate the deployment of such technologies in the industrial sector.

Capacity needs to be built in the skills and knowledge to tackle industrial electricity efficiency. This should aim at identifying and transferring lessons from successful industrial electricity efficiency policies and programmes, along with information on best practice technologies and measures that can be applied in the industrial sector.

The reliance on simple extrapolation of past growth rates or trends for forecasting electricity demand in Ghana is not up to the mark in terms of rigor and precision. This study therefore, recommends the adoption of econometric and time series techniques for purposes of obtaining accurate forecast for electricity demand which is an important condition for achieving healthy electricity market.

Given the difficulty associated with adjusting the tariff to reflect the full marginal cost, an alternative way to avoid the required huge investments in new plants is to develop and intensify appropriate demand side management programs. Specifically this study recommends that sector based efficiency standards should be implemented. Also there will be the need to intensify efficiency education at the sector level especially at the household and industrial level. Developing renewable and other cleaner forms of energy will also savage the situation in the future.

Given the fact that electricity consumption does not cause economic growth, this study recommends the development of proprietary electricity conservation measures.

6.4 Limitations and Recommendations for Future Study

The major limitation of the study is that own-price and cross-price elasticities were not obtained. This was mainly due to the reason of data unavailability given the sample period considered.

For future research, a more sector base analysis of electricity demand (industrial, commercial, residential) should be conducted. This will help establish the demand response of specific sectors and also develop sector base demand-side management programmes and efficiency standards.

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APPENDIXES

APPENDIX 1

Variable addition test

Dependent variable is dlnEC

List of variables added to the regression

lnEC (-1) lnEF (-1) lnY (-1) lnU (-1) lnV (-1)

31 observations used for estimation from 1975 to 2005

Regressor	coefficient	standard error	T-Ratio [Prob]
CON	11.0388	4.2444	2.6008[.020]
DLNEC (-1)	.8879	.4192	2.1181[.051]
DLNEC (-2)	.2934	.47123	.6226[.543]
DLNEF (-1)	1.0631	.34955	3.0413[.008]
DLNEF (-2)	.6227	.40577	1.5346[.146]
DLNY (-1)	1.0054	.73225	1.3730[.190]
DLNY (-2)	1.8682	.84367	2.2143[.043]
DLNU (-1)	1.8973	.76040	2.4952[.025]
DLNU (-2)	.6957	.63695	1.0922[.292]
DLNV (-1)	-.4851	.40418	-1.2003[.249]
DLNV (-2)	.2874	.38858	.7397[.471]
LNEC (-1)	-1.0610	.41374	-2.5645[.022]
LNEF (-1)	-.6650	.24716	-2.6905[.017]
LNY (-1)	-.9143	.70003	-1.3060[.211]
LNU (-1)	-.8611	.31964	-2.6940[.017]
LNV (-1)	1.1161	.49218	2.2677[.039]

Joint test of zero restrictions on the coefficients of additional variables:

Lagrange Multiplier Statistic CHSQ(5)= 18.0851[.003]

Likelihood Ratio Statistic CHSQ(5)= 27.1439[.000]

F Statistic F(5, 15)= 4.2010[.014]

APPENDIX 2

Variable addition test

Dependent variable is dlnEF

List of variables added to the regression

lnEC (-1) lnEF (-1) lnY (-1) lnU (-1) lnV (-1)

31 observations used for estimation from 1975 to 2005

Regressor	coefficient	standard error	T-Ratio [Prob]
CON	-15.9621	7.6194	-2.0949[.054]
DLNEF(-1)	-1.6237	.62750	-2.5876[.021]
DLNEF (-2)	-1.3603	.72843	-1.8675[.082]
DLNEC(-1)	-1.3097	.75248	-1.7405[.102]
DLNEC(-2)	-.9784	.84594	-1.1566[.266]
DLNY(-1)	-1.4743	1.3145	-1.1216[.280]
DLNY(-2)	-2.5361	1.5145	-1.6745[.115]
DLNU(-1)	-2.8412	1.3650	-2.0814[.055]
DLNU(-2)	-1.4233	1.1434	-1.2447[.232]
DLNV(-1)	.59353	.72558	.81802[.426]
DLNV(-2)	-.51569	.69757	-.73927[.471]
LNEC(-1)	1.2730	.74274	1.7139[.107]
LNEF(-1)	.96499	.44369	2.1749[.046]
LNY(-1)	1.5083	1.2567	1.2002[.249]
LNU(-1)	1.6054	.57381	2.7978[.014]
LNV(-1)	-1.3569	.88355	-1.5358[.145]

Joint test of zero restrictions on the coefficients of additional variables:

Lagrange Multiplier Statistic	CHSQ(5)= 16.7310[.005]
Likelihood Ratio Statistic	CHSQ(5)= 24.0528[.000]
F Statistic	F(5, 15)= 3.5176[.027]

APPENDIX 3

Variable addition test

Dependent variable is dlnY

List of variables added to the regression

lnEC (-1) lnEF (-1) lnY (-1) lnU (-1) lnV (-1)

31 observations used for estimation from 1975 to 2005

Regressor	coefficient	standard error	T-Ratio [Prob]
CON	2.3196	.53565	4.3304[.001]
DLNY(-1)	.17410	.092412	1.8840[.079]
DLNY(-2)	-.013303	.10647	-.12494[.902]
DLNEF(-1)	-.076886	.044114	-1.7429[.102]
DLNEF(-2)	-.12264	.051209	-2.3950[.030]
DLNEC(-1)	-.044645	.052900	-.84395[.412]
DLNEC(-2)	-.10213	.059471	-1.7174[.106]
DLNU(-1)	-.12531	.095964	-1.3058[.211]
DLNU(-2)	-.12933	.080385	-1.6089[.128]
DLNV(-1)	.034165	.051009	.66978[.513]
DLNV(-2)	-.073450	.049040	-1.4978[.155]
LNEC(-1)	.18308	.052215	3.5062[.003]
LNEF(-1)	.18487	.031192	5.9270[.000]
LNY(-1)	-.65665	.088346	-7.4327[.000]
LNU(-1)	-.062995	.040339	-1.5616[.139]
LNV(-1)	.014775	.062114	.23787[.815]

Joint test of zero restrictions on the coefficients of additional variables:

Lagrange Multiplier Statistic CHSQ(5)= 27.6208[.000]

Likelihood Ratio Statistic CHSQ(5)= 68.7064[.000]

F Statistic F(5, 15)= 24.5210[.000]

APPENDIX 4

Variable addition test

Dependent variable is dlnU

List of variables added to the regression

lnEC (-1) lnEF (-1) lnY (-1) lnU (-1) lnV (-1)

31 observations used for estimation from 1975 to 2005

Regressor	coefficient	standard error	T-Ratio [Prob]
CON	1.2500	1.3241	. 94405[.360]
DLNU(-1)	.11826	.23722	.49853[.625]
DLNU(-2)	.28381	.19871	1.4282[.174]
DLNY(-1)	.74058	.22844	3.2419[.005]
DLNY(-2)	.82249	.26320	3.1250[.007]
DLNEF(-1)	-.016863	.10905	-.15463[.879]
DLNEF(-2)	-.014398	.12659	-.11374[.911]
DLNEC(-1)	-.078686	.13077	-.60172[.556]
DLNEC(-2)	-.063060	.14701	-.42895[.674]
DLNV(-1)	.30483	.12609	2.4175[.029]
DLNV(-2)	.28202	.12123	2.3264[.034]
LNEC(-1)	.40240	.12908	3.1175[.007]
LNEF(-1)	.11242	.077107	1.4579[.165]
LNY(-1)	-.54733	.21839	-2.5062[.024]
LNU(-1)	-.42813	.099718	-4.2934[.001]
LNV(-1)	-.31540	.15355	-2.0541[.058]

Joint test of zero restrictions on the coefficients of additional variables:

Lagrange Multiplier Statistic CHSQ(5)= 20.8646[.001]

Likelihood Ratio Statistic CHSQ(5)= 34.6567[.000]

F Statistic F(5, 15)= 6.1758[.003]

APPENDIX 5

Variable addition test (OLS Case)

Dependent variable is dlnEC

List of variables added to the regression

lnEC (-1) lnEF (-1) lnY (-1) lnU (-1) lnV (-1)

31 observations used for estimation from 1975 to 2005

Regressor	coefficient	standard error	T-Ratio [Prob]
CON	-8.4923	3.2381	-2.6226[.019]
DLNV(-1)	.70016	.30836	2.2706[.038]
DLNV(-2)	-.13426	.29645	-.45290[.657]
DLNU(-1)	-1.8118	.58012	-3.1231[.007]
DLNU(-2)	-.95550	.48594	-1.9663[.068]
DLNY(-1)	.77169	.55865	1.3814[.187]
DLNY(-2)	.15769	.64365	.24499[.810]
DLNEF(-1)	-.13675	.26668	-.51279[.616]
DLNEF(-2)	-.68117	.30957	-2.2004[.044]
DLNEC(-1)	.028738	.31979	.089864[.930]
DLNEC(-2)	-.67437	.35951	-1.8758[.080]
LNEC(-1)	.32831	.31565	1.0401[.315]
LNEF(-1)	.30779	.18856	1.6323[.123]
LNY(-1)	1.3738	.53407	2.5724[.021]
LNU(-1)	.97626	.24386	4.0034[.001]
LNV(-1)	-.94512	.37549	-2.5170[.024]

Joint test of zero restrictions on the coefficients of additional variables:

Lagrange Multiplier Statistic CHSQ(5)= 19.0441[.002]

Likelihood Ratio Statistic CHSQ(5)= 29.5355[.000]

F Statistic F(5, 15)= 4.7786[.008]

APPENDIX 6

Variable deletion test (OLS Case)

Dependent variable is DLNEC

List of the variables deleted from the regression: T

31 observations used for estimation from 1975 to 2005

Regressor	coefficient	standard error	T-Ratio [Prob]
CON	11.0388	4.2444	2.6008[.020]
DLNEC(-1)	.88786	.41917	2.1181[.051]
DLNEC(-2)	.29338	.47123	.62259[.543]
DLNEF(-1)	1.0631	.34955	3.0413[.008]
DLNEF(-2)	.62271	.40577	1.5346[.146]
DLNY(-1)	1.0054	.73225	1.3730[.190]
DLNY(-2)	1.8682	.84367	2.2143[.043]
DLNU(-1)	1.8973	.76040	2.4952[.025]
DLNU(-2)	.69565	.63695	1.0922[.292]
DLNV(-1)	-.48514	.40418	-1.2003[.249]
DLNV(-2)	.28743	.38858	.73970[.471]
LNEC(-1)	-1.0610	.41374	-2.5645[.022]
LNEF(-1)	-.66498	.24716	-2.6905[.017]
LNY(-1)	-.91425	.70003	-1.3060[.211]
LNU(-1)	-.86109	.31964	-2.6940[.017]
LNV(-1)	1.1161	.49218	2.2677[.039]

Joint test of zero restrictions on the coefficients of deleted variables:

Lagrange Multiplier Statistic CHSQ(1)= .42254[.516]

Likelihood Ratio Statistic CHSQ(1)= .42544[.514]

F Statistic F(1, 14)= .19346[.667]

Appendix 7: ARIMA (1 1 2)

Dependent Variable: DLNEF
Method: Least Squares
Date: 05/09/11 Time: 14:21
Sample(adjusted): 1973 2008
Included observations: 36 after adjusting endpoints
Convergence achieved after 62 iterations
Backcast: OFF (Roots of MA process too large)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.032394	0.037641	0.860611	0.3959
AR(1)	0.426256	0.175893	2.423382	0.0212
MA(1)	-0.830576	0.250443	-3.316423	0.0023
MA(2)	-0.724062	0.272630	-2.655840	0.0122
R-squared	0.541569	Mean dependent var		0.020018
Adjusted R-squared	0.498591	S.D. dependent var		0.335347
S.E. of regression	0.237460	Akaike info criterion		0.066806
Sum squared resid	1.804396	Schwarz criterion		0.242753
Log likelihood	2.797490	F-statistic		12.60108
Durbin-Watson stat	2.343699	Prob(F-statistic)		0.000013
Inverted AR Roots		.43		
Inverted MA Roots	1.36	-.53		
	Estimated MA process is noninvertible			

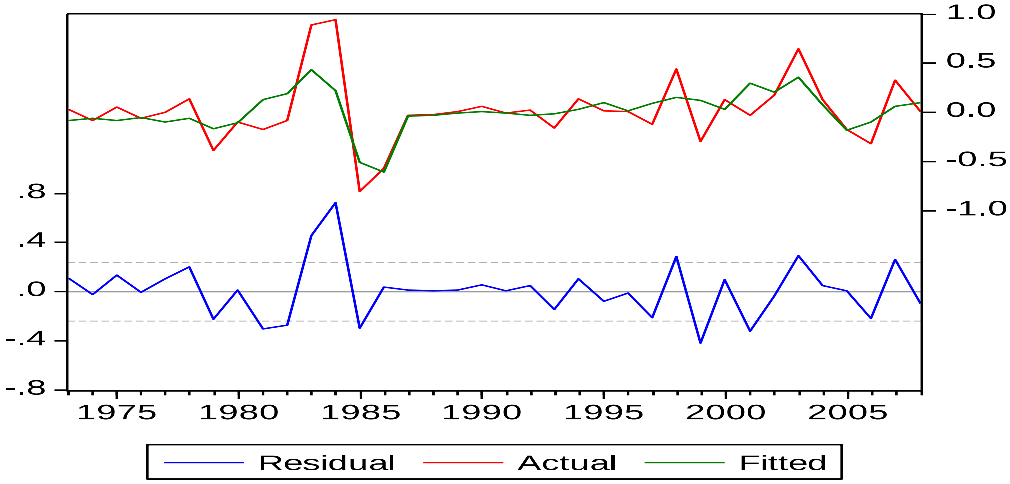
Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.788444	Probability	0.694749
Obs*R-squared	25.28261	Probability	0.390536

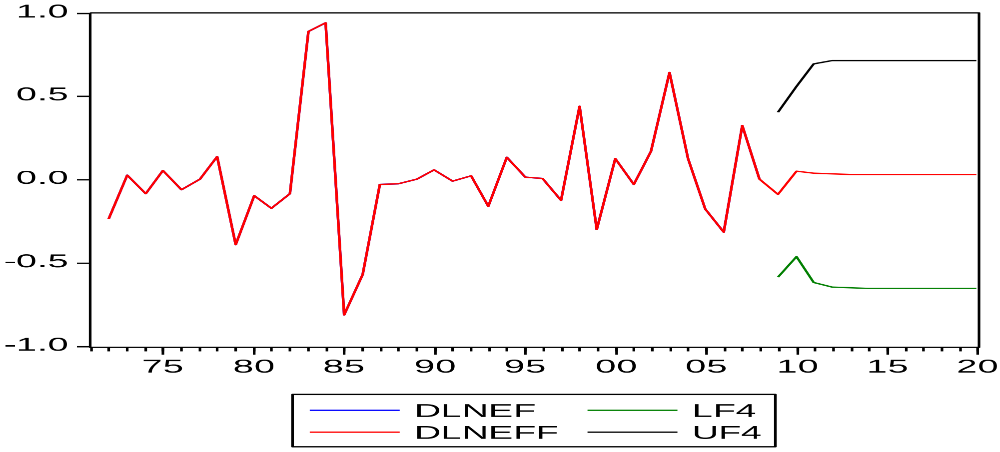
Chow Forecast Test: Forecast from 2006 to 2008

F-statistic	1.724053	Probability	0.183963
Log likelihood ratio	5.908157	Probability	0.116165

Appendix 8: Plot of residuals, atual and fitted values of the ARIMA (1 1 2) model



Appendix 9: Plot of actual and forecast values within the 95% confidence interval



Appendix 10: ARIMA (1 1 2) based forecast for change in lnef from 2011 to 2019

year	Forecast of change in lnef	Standard error of the Forecast
2009	-0.08942	0.25190
2010	0.04989	0.26102
2011	0.03985	0.3346
2012	0.03557	0.3462
2013	0.03375	0.3482
2014	0.03297	0.3486
2015	0.03264	0.3486
2016	0.032500	0.3486
2017	0.032439	0.3486
2018	0.032413	0.3486
2019	0.032402	0.3486

Appendix 11: ARIMA (2 1 2) MODEL

Dependent Variable: DLNV
Method: Least Squares
Date: 05/08/11 Time: 12:57
Sample(adjusted): 1974 2008
Included observations: 35 after adjusting endpoints
Convergence achieved after 19 iterations
Backcast: 1972 1973

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.016000	0.021133	-0.757115	0.4549
AR(1)	0.239741	0.107889	2.222111	0.0340
AR(2)	-0.820388	0.106189	-7.725736	0.0000
MA(1)	0.303881	0.086752	3.502876	0.0015
MA(2)	0.994266	0.087520	11.36040	0.0000
R-squared	0.525580	Mean dependent var		0.008757
Adjusted R-squared	0.462325	S.D. dependent var		0.165200
S.E. of regression	0.121135	Akaike info criterion		-1.252253
Sum squared resid	0.440213	Schwarz criterion		-1.030060
Log likelihood	26.91442	F-statistic		8.308793
Durbin-Watson stat	1.698615	Prob(F-statistic)		0.000123
Inverted AR Roots	12 -.90i	.12+.90i		
Inverted MA Roots	-.15 -.99i	-.15+.99i		

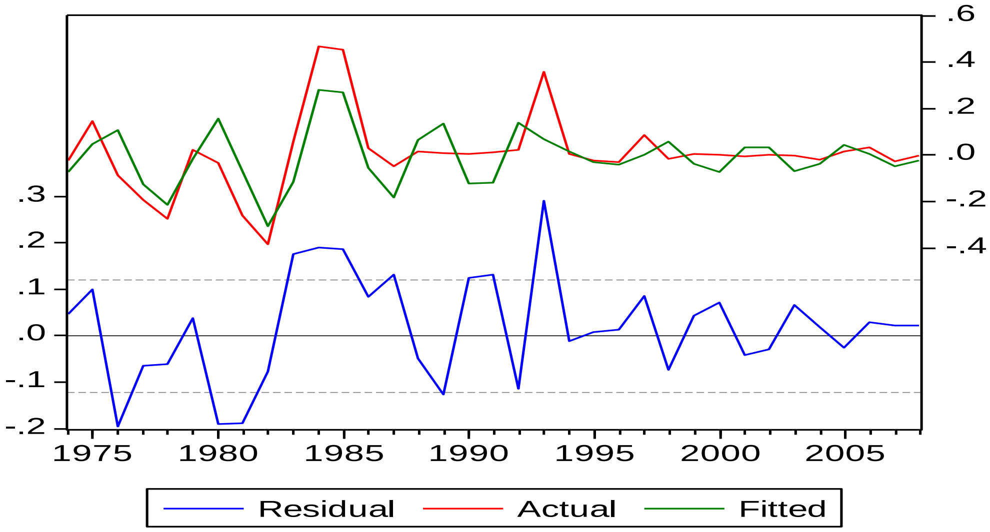
Breusch-Godfrey Serial Correlation LM Test:

F-statistic	1.756304	Probability	0.191175
Obs*R-squared	3.105708	Probability	0.211643

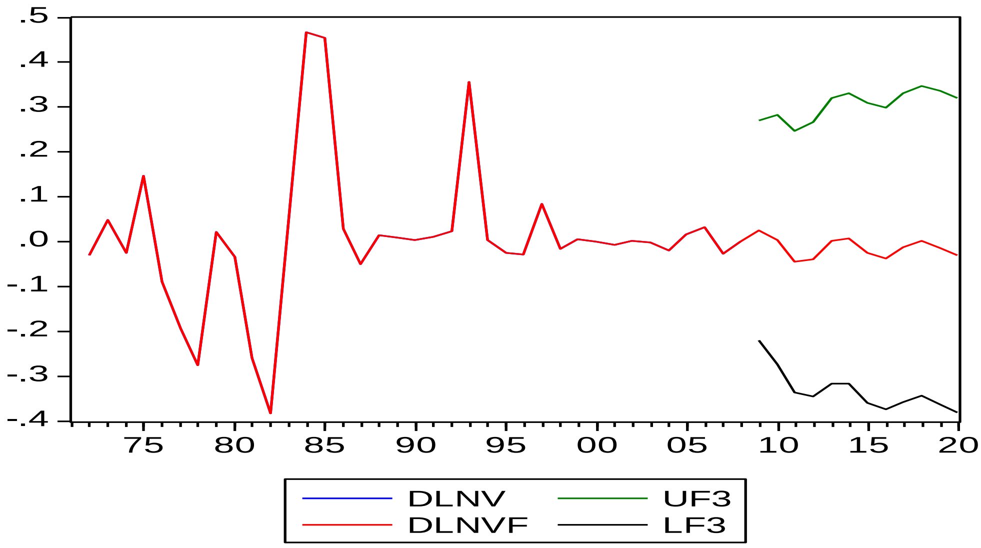
Chow Forecast Test: Forecast from 2006 to 2008

F-statistic	0.126338	Probability	0.943684
Log likelihood ratio	0.487899	Probability	0.921542

Appendix 12: Plot of residual, actual and fitted values of the ARIMA (2 1 2) model



Appendix 12: Plot of actual and forecast values within 95% confidence interval



Appendix 13: ARIMA (2 1 2) based forecast for change in Inv from 2011 to 2019

Year	Forecast of change in Inv	Standard error of the Forecast
2009	0.024820	0.125453
2010	0.003546	0.141922
2011	-0.0448	0.14887
2012	-0.0389	0.1563
2013	0.00213	0.1626
2014	0.00717	0.1654
2015	-0.02532	0.1706
2016	-0.03724	0.1718
2017	-0.01345	0.1756
2018	0.00204	0.1761
2019	-0.01377	0.1786

Appendix 14

Dynamic forecasts for the change in LNEC

Based on 34 observations from 1975 to 2008.

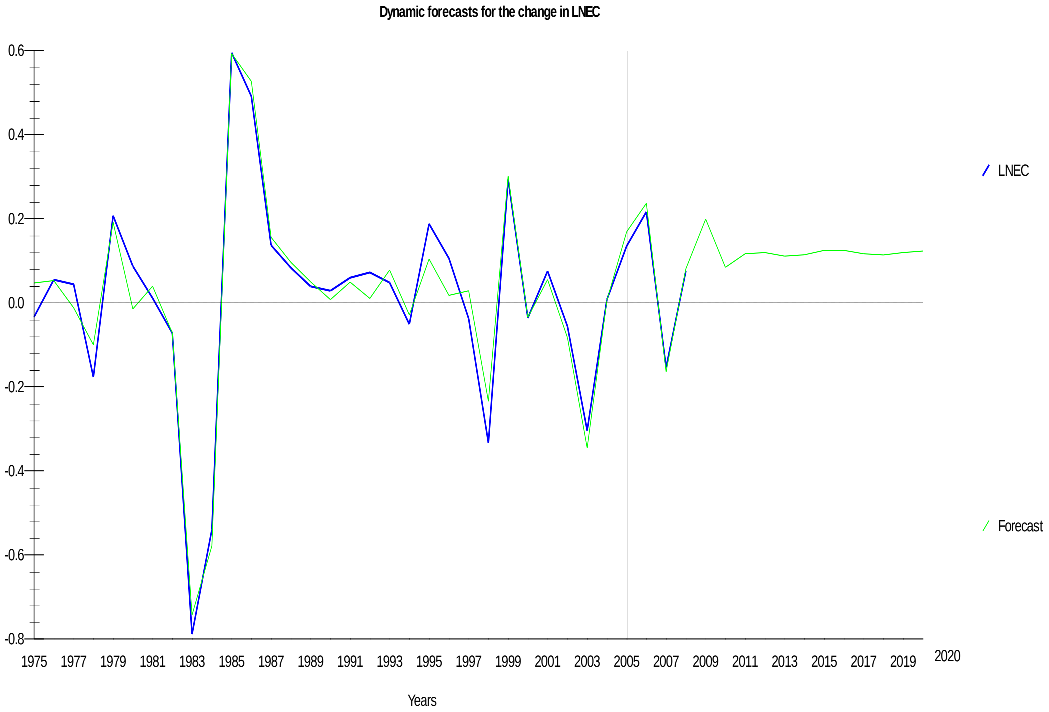
ARDL (1, 1, 0, 0, 2) selected using Akaike Information Criterion.

Dependent variable in the ARDL model is LNEC included with a lag of 1.

List of other regressors in the ARDL model: LNEF LNEF (-1) LNY LNU LNV LNV (-1) LNV (-2) CON

Observation	Actual	Prediction	Error
2009	*NONE*	.19537	*NONE*
2010	*NONE*	.081355	*NONE*
2011	*NONE*	.11271	*NONE*
2012	*NONE*	.11470	*NONE*
2013	*NONE*	.10620	*NONE*
2014	*NONE*	.10936	*NONE*
2015	*NONE*	.11979	*NONE*
2016	*NONE*	.11985	*NONE*
2017	*NONE*	.11151	*NONE*
2018	*NONE*	.10874	*NONE*
2019	*NONE*	.11455	*NONE*

Appendix 15: Plot of actual and forecast values for the dynamic forecast



APPENDIX 16

Test Statistics and Choice Criteria for Selecting the Order of the VAR Model

Based on 34 observations from 1975 to 2008. Order of VAR = 4

List of variables included in the unrestricted VAR: LNEC LNY

List of deterministic and/or exogenous variables: CON T

Order	LL	AIC	SBC	LR test	Adjusted LR test
4	86.0247	66.0247	50.7611	------	------
3	81.4585	65.4585	53.2476	CHSQ (4) = 9.1325[.058]	6.4465[.168]
2	78.6086	66.6086*	57.4505	CHSQ (8) = 14.8322[.062]	10.4698[.234]
1	71.6420	63.6420	57.5365*	CHSQ (12) = 28.7655[.004]	20.3051[.062]
0	24.9291	20.9291	17.8764	CHSQ (16) = 122.1912[.000]	86.2526[.000]

NB: AIC and SBC are based on log-likelihood, hence the maximum is chosen

Appendix 17

LR Test of Deletion of Deterministic/Exogenous Variables in the VAR

Null hypothesis	**LR test of restrictions (CHSQ)**	**Maximum value of log-likelihood**	**P-value**
Intercept but no trend	10.0772	74.5430	0.006
No intercept but trend	3.3864	77.8884	0.184
Intercept and trend	11.0271	74.0680	0.026

APPENDIX 18

Seemingly Unrelated Regressions Estimation. The estimation method converged after 0 iterations

Dependent variable is LNEC. 34 observations used for estimation from 1975 to 2008

Regressor	Coefficient	Standard Error	T-Ratio[Prob]
CON	1.3649	1.7005	.80260[.429]
T	-.0013122	.0056366	-.23280[.818]
LNEC(-1)	.85776	.18428	4.6547[.000]
LNEC(-2)	-.39723	.22722	-1.7483[.092]
LNEC(-3)	.16750	.16764	.99921[.327]
LNY(-1)	2.3465	.89941	2.6089[.015]
LNY(-2)	-.50993	1.3553	-.37624[.710]
LNY(-3)	-1.5100	.97562	-1.5477[.134]

R-Squared	.79376	R-Bar-Squared	.73823
S.E. of Regression	.19318	F-stat. F(7, 26)	14.2953[.000]
Mean of Dependent Variable	8.3997	S.D. of Dependent Variable	.37758
Residual Sum of Squares	.97031	Equation Log-likelihood	12.2166
DW-statistic	2.1912	System Log-likelihood	81.4585
System AIC	65.4585	System SBC	53.2476

APPENDIX 19

Wald test of restriction(s) imposed on parameters

The underlying estimated SURE model is: lnEC CON T lnEC {1-3} lnY {1-3}; lnY CON T lnY {1-3} lnEC {13}. 34 observations used for estimation from 1975 to 2008

List of restriction(s) for the Wald test: A6=0; A7=0

Wald Statistic CHSQ(2)= 10.8149[.004]

APPENDIX 20

Seemingly Unrelated Regressions Estimation. The estimation method converged after 0 iterations

Dependent variable is LNY. 34 observations used for estimation from 1975 to 2008

Regressor	Coefficient	Standard Error	T-Ratio[Prob]
CON	.78017	.32027	2.4360[.022]
T	.0043641	.0010616	4.1110[.000]
LNY(-1)	.96366	.16939	5.6890[.000]
LNY(-2)	-.24802	.25525	-.97164[.340]
LNY(-3)	.18140	.18374	.98726[.333]
LNEC(-1)	-.016489	.034706	-.47511[.639]
LNEC(-2)	-.0061151	.042793	-.14290[.887]
LNEC(-3)	-.014059	.031572	-.44531[.660]

R-Squared	.94288	R-Bar-Squared	.92751
S.E. of Regression	.036383	F-stat. F(7, 26)	61.3163[.000]
Mean of Dependent Variable	5.4787	S.D. of Dependent Variable	.13513
Residual Sum of Squares	.034417	Equation Log-likelihood	68.9807
DW-statistic	1.4142	System Log-likelihood	81.4585
System AIC	65.4585	System SBC	53.2476

APPENDIX 21

Wald test of restriction(s) imposed on parameters

The underlying estimated SURE model is: lnEC CON T lnEC {1-3} lnY {1-3}; lnY CON T lnY {1-3} lnEC {1-3}. 34 observations used for estimation from 1975 to 2008

List of restriction(s) for the Wald test: B6=0; B7=0

Wald Statistic CHSQ(2)= .72479[.696]